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THE TORTOSA ASTRONOMICAL OBSERVATORY.*

THE new observatory of the Ebro is situated near Tortosa in Catalonia, Spain, in latitude 40 deg. 49 min. N. and longitude 0 deg. 31 min. E., approximately. It rests upon a thick, compact and uniform geological stratum, free from magnetic substances and remote from Miocene eruptions of basalt. On the geological maps of Spain no faults are shown in the vicinity of the observatory. These conditions make the site singularly appropriate for an observatory.

The principal work of the observatory is the study of the relations existing between solar activity and terrestrial phenomena, especially magnetic and electrical phenomena. For this purpose systematic observations are made of electrical and magnetic variations, both periodic and irregular, micro-seismic movements or small tremors of the earth, meteorological phenomena and the polarization of the sky.

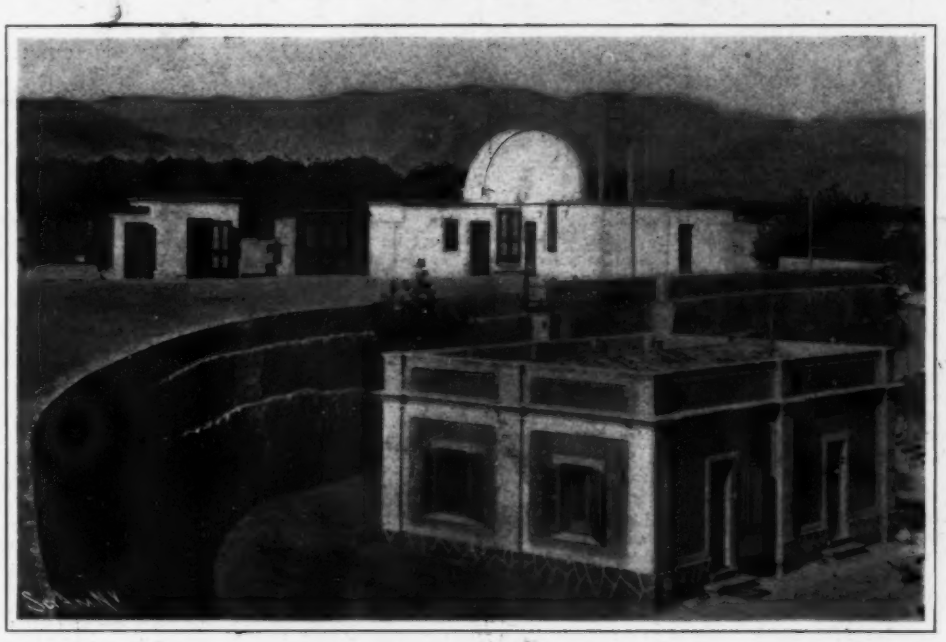
The apparatus is mounted according to the plan which is now orthodox, instruments which may be disturbed by the proximity of others or which need special conditions being placed in detached buildings.

Two separate buildings are devoted to magnetic observations. The cellar of the first is divided into two rooms, each containing a complete series of Mascart's variation instruments. One series is observed directly with telescopes, while the other furnishes a continuous photographic record on a band of paper which moves about one inch per hour. Acetylene is used as an illuminant. The second building is for absolute magnetic measurements. The declination and the horizontal intensity are measured with a Dover unifilar magnetometer, of the Kew pattern; the inclination is determined by means of an inclination inductor of the type employed in the Prussian royal observatory at Potsdam. A building in the form of a cross is assigned to the study of solar activity. In the center is the revolving dome of a small equatorial telescope which suffices for the observation of sun spots and, with the addition of a spectroscope, for that of the solar protuberances. The equatorial has two objectives, each 6½ inches in diameter. The focal length of the photographic objective is 83 inches; that of the other 94½ inches. The photographic telescope carries a fixed enlarging camera which gives a solar image 4 inches in diameter without interfering with direct work at the focus. The other telescope is equipped with Huyghens eyepieces, a precision micrometer and a spectroscope with a Rowland grating for the study of protuberances. To facilitate observation of the limb of the sun a mirror is so arranged that the observer looks always in a direction parallel to the axis of the telescope.

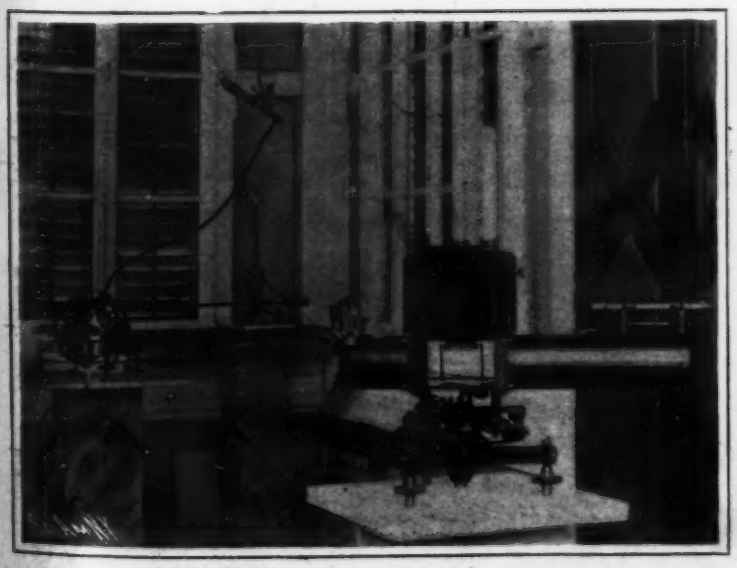
In the southern wing of this building are: (1) An Evershed spectro-heliograph with two slits by which any desired wave-length can be isolated. By isolating the spectral line K, for example, and directing the instrument to the sun's limb photographs of the chromosphere, showing the faculæ, can be obtained. The image of the sun which is thrown on the first slit is 2 centimeters (0.8 inch) in diameter. The focal length of the telescope being thrice that of the collimator the photograph of the chromosphere is 6 centimeters (2.4 inches) in diameter. To make the image truly circular the distances of the slits from the axis must be in the same ratio, 1 to 3. The spectroscope is direct-vision and has two prisms of crown glass and one of flint. The prisms were made by Tobin, the rest of the apparatus by

* From an article contributed by its director, R. Cibera, S. J., to the Memoirs of the Italian Spectroscopical Society, 1906.

THE SOLAR BUILDING AND THE PHOTOGRAPHIC LABORATORY.



ASTROPHYSICAL LABORATORY.



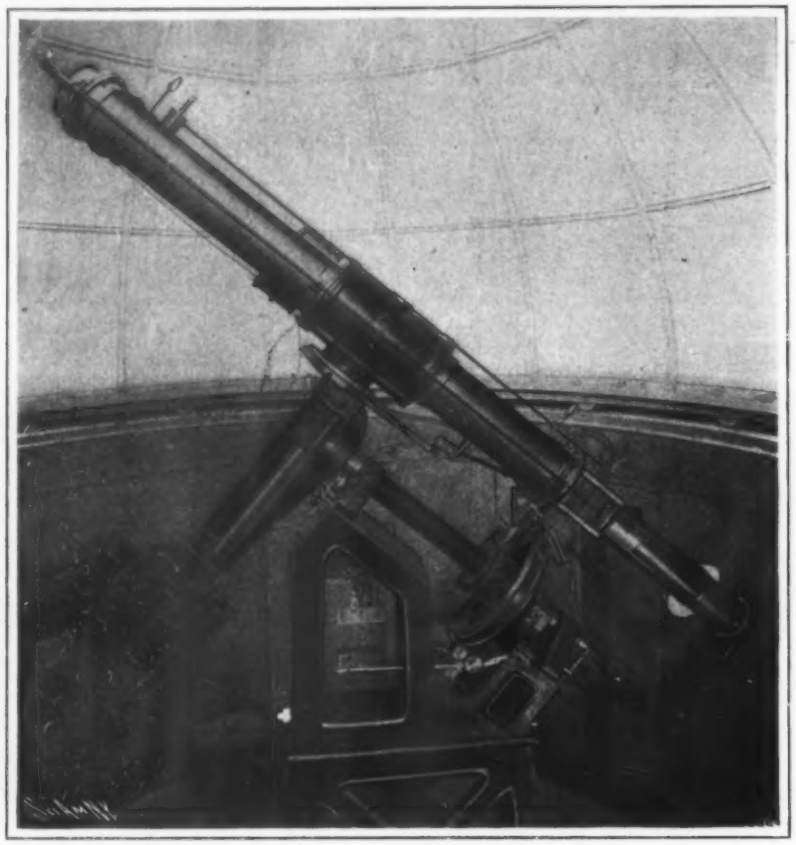
THE MAGNETOMETER ROOM.

The inclination inductor is shown on left, its galvanometer in middle, and the Dover magnetometer on right.

GERDIEN APPARATUS ON THE LEFT; ELSTER AND GEITEL APPARATUS ON THE RIGHT.

THE TORTOSA ASTRONOMICAL OBSERVATORY.

Mailhat. (2) A polar siderostat which is usually employed as a heliostat. The mirror is 8 inches in diameter. A second mirror, 7 inches in diameter, reflects the solar beam in a horizontal direction, to a lens of 6.4 inches aperture which forms an image of the sun on the slit of the collimator. (3) A spectrometer with a Rowland grating and photographic camera, made by Pellin. The grating is 2 7/16 inches wide and has 568 lines to the millimeter (14,367 to the inch). The 16-inch disk of the spectrometer is large enough to carry, instead of the grating, a battery of four large prisms of 2.4 inches aperture and 20 inches focal length. The observing telescope can be replaced by a photographic camera for plates of 2.6 by 3.6 inches. It is intended to use this apparatus especially for the study of the radial velocity of solar eruptions.



DOUBLE EQUATORIAL TELESCOPE.

By turning the second mirror of the heliostat through a right angle the image of the sun can be thrown on the slit of the spectrometer but, in order to use the spectrometer and the spectro-heliograph simultaneously another heliostat, with second mirror and lens, has been ordered.

The east wing of the solar building contains a meridian circle with a 3-inch objective and a micrometer eyepiece. The graduated circle, of silver, is read to 2 seconds of arc by means of two micrometer microscopes. The telescope can be inverted. The sidereal clock has a Riefflер pendulum and has been tested at the Paris observatory.

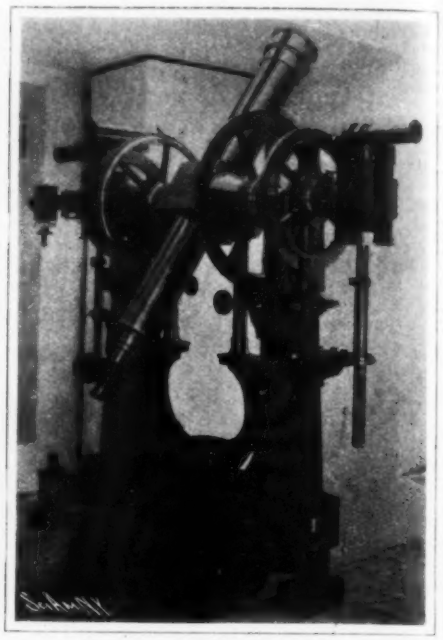
The north wing contains a mean solar clock which sends a synchronizing current every second to the clock of the meteorological building and a current every minute to the seismographs. By a special apparatus a stronger current is sent every hour to each of the magnetic and electrical registering instruments where it causes an electric lamp, placed in front of a slit, to glow and thus prints a black line on the photographic film to mark the exact beginning of the hour. We attach great importance to the precise registration of the times of observations.

The north wing also contains a small equatorial telescope which can be rolled out on a platform for observations in the open air.

The west wing contains a small photographic laboratory for astronomical work. The main laboratory is situated near the office and residence building.

A fourth building contains the electrical and meteorological instruments with the exception of those which must be placed near the ground and which are housed in a special shed. The electric potential is measured by two Mascart quadrant electrometers of different sensibilities for ordinary and unusually high potentials. A water-dropping collector is employed, as the use of radium would interfere with ionization observations in the same building. Earth currents in two mutually perpendicular directions, S. S. E. and E. N. E., are measured by Deprez-d'Arsonval galvanometers, whose indications are recorded photographically on the same sheet with those of the electrometer. There is also a storm recorder constructed under the direction of M. Branly and employing his tripod as a coherer. The meteorological section, which is of secondary importance in this observatory, has instruments for direct reading as well as Richard recording apparatus. There is an actinometer for the measurement of solar radiation and a Cornu photopolarimeter for determining the polarization of the sky. The directions and velocities of clouds are measured very successfully with Besson's nebuloscopic grating and a large refraction nebuloscope.

A fifth building, almost entirely underground, contains the seismographic apparatus, comprising Grablovitz horizontal pendulums and a Vicentini tri-dimensional micro-seismograph, which responds to distant earthquakes. The buildings are scattered over a hill which overlooks the beautiful valley of the Ebro, near Tortosa and within 1¼ mile of the railway from Barcelona to Valencia. The almost continual clearness of the sky and the absence of electric railways and other sources of magnetic disturbance make the site very favorable, while the proximity of the Jesuit college supplies us with earnest assistants destined, perhaps, to carry on the work at Manila and other places where science as well as religion is confided to the care of missionaries.



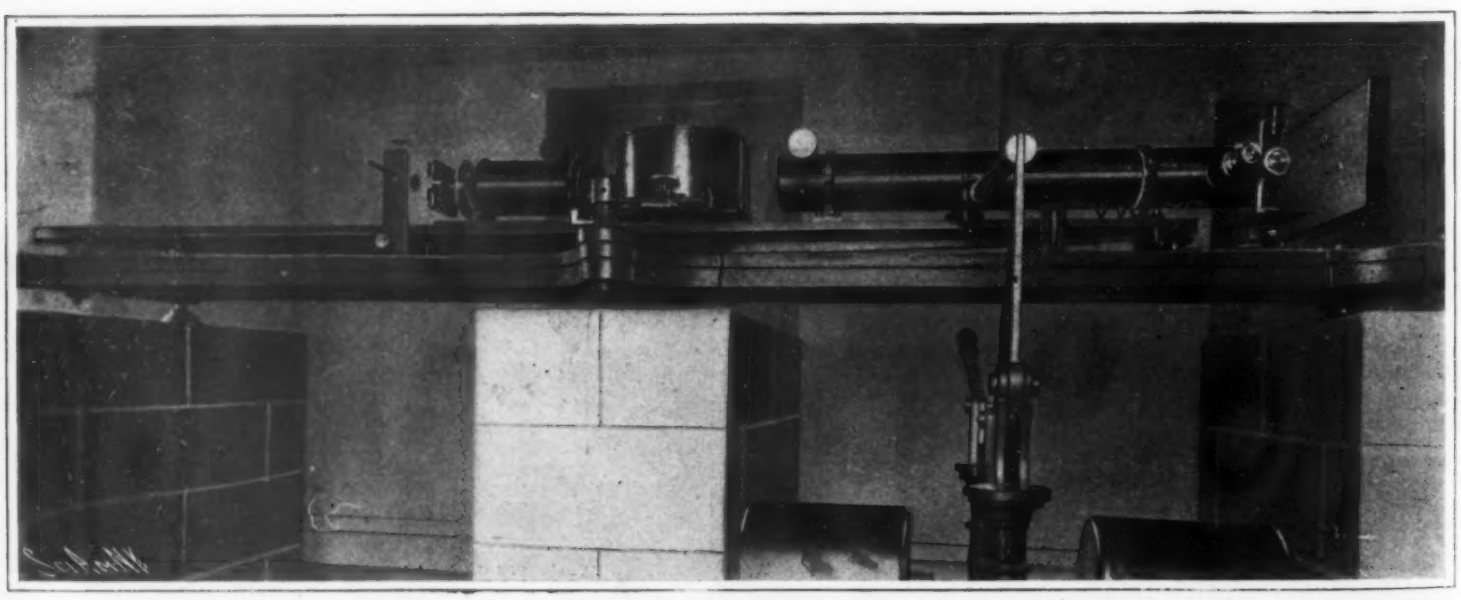
THE MERIDIAN CIRCLE.

THE CONSTRUCTION OF THE HEAVENS.*

By HECTOR MACPHERSON, JR.

AMONG the problems of astronomy the supreme place is held by that popularly known as the construction of the heavens. Ever since the Copernican system of the world was established, students of the heavens have aspired to a knowledge of the structure of that vaster system, in which the stars and their attendants are mere units. Regarding the great Stellar Universe, the opinions of Copernicus and his immediate successors, Tycho Brahe, Galileo, and Kepler were extremely crude and supported by no observational evidence. More definite and scientific opinions were expressed by Huyghens, who made several interesting calculations on stellar size and distance; but the work of Newton and his successors in gravitational astronomy diverted the attention of astronomers from a question regarding which there was little data on which to build theories. Early in the eighteenth century what was afterward

* From Popular Astronomy.



EVERSHED SPECTROHELIOGRAPH.

THE TORTOSA ASTRONOMICAL OBSERVATORY.

known as the "disk-theory" of the universe was enunciated by Thomas Wright, a self-taught English astronomer. Similar views were expressed by the philosopher Kant; and some remarkable speculations were made by the German mathematician Lambert. But the scientific study of the subject did not commence until the arrival on the scene of William Herschel, the greatest astronomer of his day and perhaps the greatest observer the world has ever seen.

Herschel saw that before any rational idea of the structure of the heavens could be gained it was necessary to ascertain facts concerning the distribution of the stars. In 1784 he commenced a survey of the heavens, in order to ascertain the number of stars in various parts of the sky. This method, which he named "star-gaging," consisted in counting the number of stars in the telescopic field. Totally he secured 3,400 gages. His studies showed that in the region of the Galaxy, the stars were much more numerous than toward the galactic poles. Sometimes he saw as many as 588 stars in a telescopic field, at other times only two. Assuming that the stars were on the average of about the same size, and scattered through space with some approach to uniformity, Herschel was able to compute the distance to which his telescope penetrated into space, and, assuming that the universe was limited in extent and that his gaging-telescope was sufficiently powerful to penetrate the Milky Way, he was enabled to sketch the shape and extent of the universe. He concluded that the universe extended in the direction of the Galaxy to 830 times the distance of first magnitude stars. He was enabled to sketch the form of the universe, which he regarded as cloven at one of its extremities, the cleft being represented by the well-known bifurcation in the Milky Way. The universe was in fact supposed to be a cloven disk and the Milky Way merely a vastly extended portion of it, not a region of actual clustering.

Strange to say, Herschel's original ideas regarding the universe were for many years accepted by astronomical writers. Arago accepted the original theory, unaware that Herschel had in reality abandoned it, and in this he was followed by a host of French and English writers, who did not take the trouble to read each of Herschel's papers, merely quoting that of 1785, and believing it to represent his final views on the subject. Meanwhile, the observations made by Herschel himself proved fatal to the disk theory. Even in 1785 he believed that there were regions in the Milky Way where the stars were more closely clustered than others. "It would not be difficult," he wrote in that year, "to point out two or three hundred gathering clusters in our system." These ideas were soon confirmed; and, although in 1799 he still adhered to the disk theory, in 1802 he wrote: "I am now convinced by a long inspection and continued examination of it that the Milky Way itself consists of stars very differently scattered from those which are immediately about us. This immense starry aggregation is by no means uniform. The stars of which it is composed are very unequally scattered"—a conclusion quite opposed to the disk theory, where the Milky Way was supposed to be merely an extended portion of the universe.

In 1811 Herschel wrote as follows: "I must freely confess that by continuing my sweeps of the heavens, my opinion of the arrangement of the stars and their magnitudes, and some other particulars, have undergone a gradual change; and, indeed, when the novelty of the thing is considered we cannot be surprised that many things formerly taken for granted should on examination prove to be different from what they were generally, but incautiously, supposed to be. For instance, an equal scattering of the stars may be admitted in certain calculations; but when we examine the Milky Way, or the closely compressed clusters of stars, of which my catalogues have recorded so many instances, this supposed equality of scattering must be given up." This was the virtual abandonment of the disk theory. Six years later, Herschel announced that in six cases he had failed to resolve the Milky Way. This was the abandonment of the second of his assumptions, namely, that his telescope was sufficiently powerful to penetrate to the limits of the universe. Although now an old man, Herschel attacked the question again. In 1817, he devised another method of star-gaging, which Arago and other writers have confused with that of 1785. The two methods, however, were quite distinct. In the first system, one telescope was used on different regions of the heavens; whereas, in the second, various telescopes were used on identical regions. The principle was that the telescopic power necessary to resolve groups of stars indicates the distance at which these groups lie. This, however, also assumed an equal scattering of the stars, and as Proctor remarks: "No question can exist that the principle is unsound, and that Herschel would himself have abandoned it had he tested it early in his observing career. . . . In applying it, Sir W. Herschel found regions of the heavens very limited in extent, where the brighter stars (clustered like the fainter) were easily resolved with low powers, but where his largest telescopes could not resolve the faintest. These regions, if the principle were true, must be long spike-shaped star-groups, whose length is directed exactly toward the astronomer on earth —an utterly incredible arrangement."

Herschel's last observation, in 1821, showed that in parts, he could not resolve the Galaxy, even with his forty-foot reflector. In an error of translation into German and French, Struve left the impression that Herschel believed the universe to be infinite in extent —an unfortunate mistake, which hindered the progress of this branch of astronomy for years. So far was Herschel from thinking that the universe was infinite that he still thought some of the star-clusters might be external galaxies, although he had not proved the universe to be limited. Had Herschel lived, he would probably have shown what it was left for the philosopher Herbert Spencer to prove—that all the star-clusters and nebulae which we see are included within the bounds of our finite Galaxy. The result of this misapprehension regarding Herschel's ideas was that for half a century the utmost confusion prevailed among astronomers as to what Herschel had actually thought about the various points under discussion.

After the death of Herschel, little was done to further our knowledge of stellar distribution or the construction of the heavens. In this branch, as elsewhere, Herschel's direct successor was his son, Sir John Herschel, whose star-gages, both in England and South Africa, were a worthy sequel to those of his father. In his various works on astronomy, John Herschel reproduced the disk-theory, evidently unaware that the elder Herschel had himself abandoned it. The work of the younger Herschel was entirely supplementary to that of his father. To Wilhelm Struve, the great German astronomer, belongs the credit of showing that the disk-theory was untenable and that Herschel had himself abandoned it. This he was enabled to do after a perusal of Herschel's papers, presented to him by Sir John Herschel. Having shown this, he undertook a series of investigations which resulted in his own theory of the universe, which appeared in his work, "Etudes d'Astronomie Stellaire," which was published in 1847. Struve's researches were based on the star-catalogues of Bessel, Piazzi and others; and dealing with 52,199 stars, he discussed the number of stars in each zone of Right Ascension. In the words of Mr. Gore, he found that "the numbers increase from hour i to hour vi, where they attain a maximum. They then diminish to a minimum at hour xiii, and rise to another but smaller maximum at hour xviii. As the hours vi and xviii are those crossed by the Milky Way, the result is very significant." Struve considered the phenomenon of the Galaxy to be produced by a collection of irregularly-condensed star-clusters, the stars being condensed in parallel planes. Next, he considered the universe to be infinitely extended in the direction of the Galaxy, and accordingly he put forward the idea that the light from the fainter and more distant stars was extinguished in its passage through space, which he regarded as only imperfectly transparent. But the extinction theory as put forward by Struve was disposed of by Sir John Herschel, who remarked that we were not at liberty to believe that in one portion of the sky, our view was limited by extinction, while at another a view could be had right through the Galaxy; and by the late Professor Grant, of Glasgow, who showed that were the theory true, the Galaxy should present a uniform appearance throughout its course. On the whole, Struve's theory was no improvement on Herschel's for, as Encke pointed out, Struve's hypothesis was built on five assumptions, all of which were questionable.

At the time of Struve's investigations, Mädler, at Dorpat, in Russia, was engaged in an attempt to solve the problem of the construction of the heavens by quite another method, that of stellar proper motion. Mädler commenced his investigation with a view to discovering the central body of the sidereal system. It was obvious to Mädler, that if such a center existed, the motions near it would be somewhat different from those in the solar system. In the solar system, the planets nearest the sun move swiftest, owing to the strength of the force of gravitation. In the sidereal system, on the other hand, as Mädler pointed out, the movements at the center would be slowest. As there would be no large preponderating body, the mutual attractions of the different stars would cause the bodies at the boundaries of the universe to move faster than those at the center, the central sun—the object of Mädler's search—being in a state of comparative rest. Accordingly he began to search the heavens for a region of sluggish proper motion. In the constellation Taurus, he noticed that the proper motions of the stars were very slow, and after a most laborious investigation, he announced that the star which fulfilled the conditions of a central body was Alcyone, the brightest of the Pleiades, a group possessed of no proper motion except that due to the sun's drift in the opposite direction. Mädler's hypothesis was published in 1846 in his work "The Central Sun" and he supplemented it with the sublime thought that the center of the universe was the abode of the Creator. In 1817 Struve rejected Mädler's theory as "much too hazardous"; and this has been the general opinion of astronomers. Mädler's theory is now regarded as quite untenable.

A unique place in the history of this branch of astronomy is held by the researches of R. A. Proctor. Not only did Proctor make fresh discoveries, but it fell to him to clear away the erroneous ideas regarding the construction of the heavens, and to put the study on a new basis. In 1870 Proctor plotted on a single chart all the stars, to the number of 324,198, contained in Argelander's great Durchmusterung charts. This work gave the deathblow to the disk theory. In his own words: "In the very regions where the Herschelian gages showed the stars to be most crowded, my chart of 324,198 stars shows the stars of the higher orders (down to the eleventh magnitude) to be so crowded that by their mere aggregation within the mass they show the Milky Way with all its streams and clusterings. It is utterly impossible that excessively remote stars could seem to be clustered exactly where relatively near stars were richly spread."

Proctor also showed that in all probability the stars composing the nebulous light of the Galaxy are much smaller than the brighter stars, and not at so great a distance as their faintness would lead us to suppose, a conclusion confirmed by the more recent work of Signor Celoria, now director of the observatory in Milan. Proctor was not so fortunate in theorizing as in direct investigation. He thought the Magellanic clouds were possibly external galaxies; and further, he put forward the idea that the Milky Way is a spiral, the gaps and "coalsacks" being due to loops in the stream, but neither of these ideas has found favor with astronomers. The chief work accomplished by Proctor was a complete revision of our knowledge of the universe, which he thus describes: "Within one and the same region co-exist stars of many orders of real magnitude, the greatest being thousands of times larger than the least. All the nebulæ hitherto discovered, whether gaseous or stellar, irregular, planetary, ring-formed or elliptic, exist within the limits of the sidereal system. They all form part and parcel of that wonderful system, whose nearer and brighter parts constitute the glories of our nocturnal heavens."

Proctor's discovery of the excess of bright stars on the Galaxy was confirmed by the researches of the late J. C. Houzeau, director of the Brussels Observatory, and some time later by Mr. J. E. Gore, the famous Irish astronomer. Mr. Gore carefully examined the positions of all the bright stars in both hemispheres, and following this he made an enumeration of the stars in the atlas of Heis and the charts of Harding. The outcome of Mr. Gore's investigation was to show that stars of each individual magnitude, taken separately, tend to aggregate on the Galaxy, the clustering being noticed even in the case of first magnitude stars. Mr. Gore further pointed out the close connection between the lucid stars and the galactic light. A similar investigation was undertaken in 1889 by the great Italian astronomer Professor Schiaparelli, formerly director of the Milan Observatory. Basing his work on the catalogue of Gould and the photometric measures of Professor Pickering, Professor Schiaparelli constructed a series of planispheres which demonstrated the crowding of the lucid stars toward the galactic plane. These investigations were still further continued by Professor Simon Newcomb, who demonstrated that "the darker regions of the Galaxy are only slightly richer in stars visible to the naked eye than other parts of the heavens, while the bright areas are between 60 and 100 per cent richer than the dark areas."

Perhaps the most elaborate investigation yet made on the construction of the heavens is that of the Dutch astronomer, Professor Kapteyn, who commenced his researches in this branch of astronomy in 1891. In that year he demonstrated that stars are bluer and more easily photographed in the Galaxy than elsewhere, a discovery confirmed by Sir David Gill and Professor Pickering. In 1893 Professor Kapteyn announced the conclusions drawn from his investigations, derived from a novel method of studying the distances of the stars from their proper motions. In order to reach a definite idea of the distances of the stars he made use of the component of the proper motion measured at right angles to a great circle of the sphere which passes through a given star and the apex of the solar motion. He found that stars of the first spectral type have smaller proper motions than those of the second, indicating that stars of the second type are on the average nearer to the solar system than those of the first, the near vicinity of the sun containing almost exclusively second-type stars. Professor Kapteyn concluded that this group of second-type stars formed one system, which he termed the solar cluster, believed by him to be roughly spherical in shape. In 1902 he abandoned the idea of a solar cluster, retaining however his opinions as to the relative distance of the different types. As Dr. Kapteyn remarked in a letter to the writer, that the second-type stars are, on the average, nearer to the solar system than the first, is an incontrovertible fact.

The structure and extent of the universe were ably discussed by Professor Simon Newcomb in his work "The Stars" which appeared in 1901. He considers that the universe is limited in extent, in accordance with the original views of Herschel, and in opposition to the opinions of Struve. He has brought clearly before his readers a calculation—originally mentioned by Olbers—based on the known fact that there are three times as many stars of any given magnitude as of that immediately brighter, the increase of number compensating for the decrease of brilliance. Were the universe infinitely extended the whole heavens would shine with the brilliance of the sun. Professor Newcomb, therefore, concludes that "that collection of stars which we call the universe is limited in extent." Positive evidence that this is the case was obtained by Professor Celoria, in the course of a series of star-gages at the north galactic pole. Using a small refractor, showing stars barely to the eleventh magnitude, he was enabled to see exactly the same number of stars as Herschel's large reflector, indicating that increase of optical power will not increase the number of stars visible in that direction. Professor Celoria's observation can only be explained on the assumption that the universe is limited in extent. Otherwise, Herschel's telescope would have shown more stars than Celoria's, even granting an extinction of light, which theory—at least as advanced by Struve—has been shown by Professor Newcomb, Dr. Seeliger, Professor Schiaparelli and others to be absolutely untenable. That the visible universe is limited in extent seems to be about all that we know for certain concerning the structure of the heavens, and even this has been questioned by Mr.

Maunder, Professor Turner and other English astronomers, in their reply to the famous theory of Dr. Russel Wallace; but here the English astronomers forgot that on one point, that of the extent of the universe, Dr. Wallace and the majority of astronomers are in complete agreement.

A series of investigations on stellar distribution commenced in 1884 by Professor Seeliger, director of the Munich Observatory, have led that distinguished astronomer to some remarkable conclusions. Professor Seeliger believes the universe to be flattened at the galactic poles, the Galaxy itself representing the zone of stellar condensation. He computes the distance of the solar system from the inner border of the zone to be about 500 times the distance of Sirius, while the external border of the universe is at 1,100 times that distance. The universe is finite in extent, its limits being about 9,000 light years from the solar system. In Professor Seeliger's opinion, the extinction of light may come into play beyond our universe, and prevent us seeing other possible collections of stars—external universes.

The question of external universes is purely a hypothetical one; we have never seen these universes, and probably never will. Still there is much to be said in favor of the idea. The question was approached from a scientific standpoint by Mr. Gore, in his masterly work "The Visible Universe," which should be perused by every student of the sublime problem. Mr. Gore regards the solar system as a system of the first order, and the Galaxy and its hypothetical fellow-universes as of the second, the Galaxy bearing the same relation to its fellow-universes that the solar system bears to the systems of Sirius or Alpha Centauri, or—to go lower in the scale—the earth-moon system to the satellites of Jupiter. Assuming that the distance between the Galaxy and the nearest external universe is proportional to that separating the sun from Alpha Centauri, he reaches the amazing conclusion that the distance of the nearest Galaxy is no less than 520,149,600,000,000,000 miles, a distance which light—which darts from the earth to the moon in a second and a half, and across the solar system in eight hours—with an inconceivable velocity of 186,000 miles a second—would take nearly ninety millions of years to traverse. Truly, as M. Flammarion says, our Milky Way is but a point in the Infinite. These calculations absolutely overwhelm the mind, and here science must give way to religion. Mr. Gore sums up his masterly investigation with the following noble words: "Although we must consider the number of *visible* stars as strictly finite, the number of stars and systems really existing but invisible to us may be practically infinite. Could we speed our flight through space on angel wings beyond the confines of our limited universe to a distance so great that the interval which separates us from the remotest fixed star might be considered as merely a step on our celestial journey, what further creations might not then be revealed to our wondering vision? Systems of a higher order might there be unfolded to our view, compared with which the whole of our visible heavens might appear like a grain of sand on the ocean shore, systems perhaps stretching out to infinity before us, and reaching at last the glorious 'mansions' of the Almighty, the Throne of the Eternal."

NEW LOW TEMPERATURE PHENOMENA.*

By Prof. Sir James Dewar, M.A., LL.D., D.Sc., F.R.S., M.R.I.

The porosity of matter, and the possibility of the occlusion of gases in it, has been the subject of scientific thought for ages. As early as 1674, Boyle,† under the title "Suspicions about the hidden Qualities of Air," writes: "It may not seem altogether improbable, that some bodies we are conversant with, may have a peculiar disposition and fitness to be wrought on by, or to be associated with, some of those exotic effluvia that are emitted by unknown bodies lodged underground, or that proceed from this or that planet. . . . We may be allowed to consider whether among the bodies we are acquainted with here below, there may not be found some that may be receptacles, if not also attractives, of the sidereal and other exotic effluviums that rove up and down in our air." While other matters took up his immediate attention, this one was not lost sight of, for ten years later, in 1684, he returns to the subject in a special discourse, "Experiments and considerations about the porosity of Bodies,"‡ in which he says: "When I consider how much most of the qualities of bodies, and consequently their operations, depend upon the structure of their minute and singly invisible particles, and that to this latent contexture, the bigness, the figure, and the collocation of the intervals and pores do necessarily concur with the size, shape, and disposition, or contrivance, of the substantial parts, I cannot but think the doctrine of the small pores of bodies of no small importance to natural philosophy." Felix Fontana, the famous physicist to Duke Ferdinand II. of Tuscany, seems to have been the first to have discovered the absorptive power of hot charcoal for gases, a property which he communicated to Priestley, about 1770, and which Priestley confirmed. Lowitz, in 1791, noticed that charcoal decolorized organic solutions. Later experiments were made by Morozzo, and another series of observations were made by two Dutch physicists, Rouppe and Norden. Shortly after this, early in last century, the subject of the action of gases on charcoal was elaborately examined by Theodore de Saussure. Subsequently Graham and Stenhouse added valuable contributions to the inquiry. The thermal evolutions of some gaseous absorptions in charcoal were determined by Faure and Silbermann; and later, Hunter showed the advantage of using cocoanut charcoal, and made a long series of investigations on the absorption of organic vapors and gases by this variety of charcoal.

In de Saussure's experiment a piece of red-hot charcoal was plunged under mercury, and introduced into the gas to be absorbed after it was cool, without allowing it to come in contact with air. He made use of box-wood charcoal, about which he remarks that it absorbed so little mercury during the cooling that it would readily swim on water. His experiments were conducted at ordinary temperature and pressure, and gave the results in the annexed table, the unit volume being that of the absorbing charcoal. For comparison, similar experiments made by Hunter with cocoa-nut charcoal are given.

	Boxwood (Saussure)	Cocoa-nut (Hunter)
Ammonia	90	172
Hydrochloric acid	85	—
Sulphurous acid	65	—
Sulphuretted hydrogen	55	—
Nitrous oxide	40	86
Carbonic acid	35	68
Olefiant gas	35	75
Carbonic oxide	9·42	21
Oxygen	9·25	18
Nitrogen	7·5	15
Hydrogen	1·75	4

He found that even if the charcoal were moistened with water, it was still capable of absorbing one-third to one-half the amount of gas absorbed when quite dry.

During these experiments he called attention to the evolution of heat during absorption, and remarked that it appeared to increase with the absorbability of the gas.

In further experiments he considered the effect of pressure on the amount of absorption, and found that absorption by volume is far greater in a rare than in a dense atmosphere, but that if reckoned by weight it is more considerable in the latter than in the former state.*

He continued similar experiments with meerschaum,

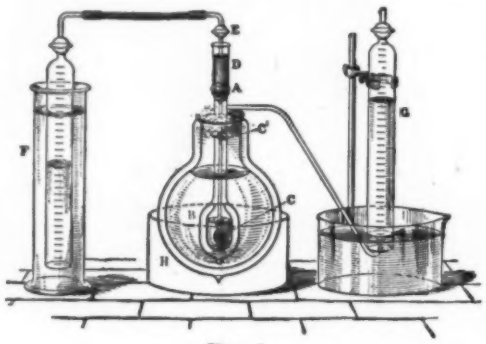


Fig. 1.

asbestos, and other substances, and also examined the effect of mixed gases.

Hunter examined the absorption of vapors by cocoanut charcoal at or above their boiling points with interesting and suggestive results as regards selective action. The following table is a selection made from some of his observations:

Cocoa-Nut Charcoal Absorption of Vapours at Boiling Point of Liquid (Hunter).

Carbon tetrachloride	4
Chloroform	30
Ethyl iodide	36
Alcohol	141
Benzol	59
Carbon bisulphide	117
Ether	87
Ethylamine	127
Water	55

In a note read before the Royal Society of Edinburgh in March, 1874, connected with a research undertaken in association with the late Prof. Tait, the absorptive power of charcoal was employed for the first time in the production of high vacua. A piece of cocoa-nut charcoal was placed in a glass tube, into which were sealed two platinum terminals for electric sparking. The tube was exhausted by the mercury pump, while the charcoal was at the same time heated to a red heat. On sealing off the tube, and allowing the charcoal to cool, the vacuum was so perfect that no spark would pass between the terminals, from a coil giving quarter-of-an-inch sparks in air. Similar experiments were repeated when investigating the theory of the motion of the Crookes radiometer, and are detailed in Nature in 1875.

One advantage of charcoal vacua in the study of electric discharges is that on heating the charcoal slowly, and connecting the platinum terminals to the induction coil, the striæ may be reproduced and maintained at any degree of rarefaction desired, and as often as we please.

At the conference on May 24, 1876, in connection with the Loan Collection of Scientific Apparatus at South Kensington, I showed a further simplification and advance in the production of high vacua. A little fluid bromine was placed in a tube, and the tube was put in a water bath, so that the bromine boiled off. Meanwhile the charcoal in another part of the tube was heated in the usual way, and when all the bromine had been vaporized the tube was sealed off. On the charcoal cooling it absorbed the bromine so thoroughly that no trace of color was visible. In this

Fig. 2.

way a vacuum is produced without the use of any exhausting pump.

Although all charcoals exhibit absorptive powers of a high order, nevertheless differences are noticeable. Among charcoals got from wood, the denser woods seem to produce the more absorptive charcoals. Thus boxwood charcoal is more absorptive than fir charcoal. Saussure found the following relative absorptive powers from different wood charcoals:

	Sp. gr.	Absorption.
Cork	0·1	Imperceptible.
Fir	0·4	4 its vol. of air.
Boxwood	0·6	7½ "
Russiberg coal (vegetable origin)	1·3	10½ "

But at last the porosity must become so fine that absorption again disappears. Thus Cumberland black lead (which is 96 per cent carbon), of sp. gr. 2.17, showed no absorption.

From experiments, detailed on a former occasion,* undertaken to determine the effect of various substances in a state of fine division placed within the walls of vacuum vessels in protecting the contents of the vessels from external heat, by reason of bad thermal conductivity and the interference of the mean free path of the gas molecules, I found that charcoal and lampblack were nearly equally good at the temperature of liquid air, and that each was four times as good as graphite.

From some recent investigations I find that charcoals so different in their origin as cocoa-nut charcoal and charcoal from cane sugar differ but little in their absorptive powers for a gas like hydrogen.†

Mitscherlich specially studied the nature of porosity in connection with the occlusion of gases. Taking a piece of charcoal weighing 0.9565 gramme, and thoroughly saturating it with water, he found that it weighed 2.2585 grammes in air, and 0.110 gramme under water. Hence of the gross volume of the charcoal, ⅝ was occupied by charcoal substance, and ⅝ was free space into which gases might be absorbed. Saussure found that charcoal at 12 deg. C. and ordinary pressure absorbed 35 times its volume of carbonic acid, but as this occupied ⅝ of the gross volume of the

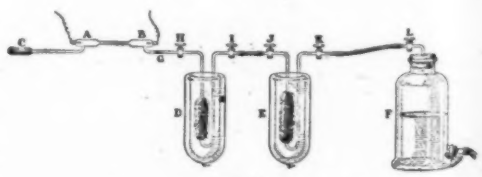


Fig. 3.

charcoal, it was actually forced into a space equal to only 1/56 of its original volume. He concluded, therefore, that about a third of the gas was liquefied in the pores of the charcoal.‡

* Read before the Royal Institution of Great Britain.
† Boyle, Works, vol. iii., p. 470, col. 1.
‡ Boyle, Works, vol. iv., p. 208, col. 1.

* Saussure's results for carbonic acid may be represented by the formulæ:

$$v = 15.3 + \frac{551.7}{p}$$

$$v = 19.1 + 0.53\,p;$$

where v is the volume absorbed, measured as above, and p is the pressure in inches of mercury.

* Liquid Air as an Analytic Agent, Roy. Inst., 1 Ap. 1898.

† Approx. Series of 30/10/04, range 250 c.c. to 2750 c.c., gave $\log. p = -\cdot 08 + \cdot 267\,c.$ Cocoa-nut.
Series 4/11/04, range 250 c.c. to 2250 c.c., gave $\log. p = \cdot 39 + \cdot 195\,c.$ Cane-sugar.
If $p = 100$ mm., these give respectively
$c. = \frac{2 \cdot 08}{\cdot 267} = 7 \cdot 8$, Cocoa-nut;
and $c. = \frac{1 \cdot 61}{\cdot 195} = 8 \cdot 3$. Cane-sugar.

‡ From Amagat's observations, the amount liquefied was almost exactly one-fifth.

He found that the cells of the charred wood are on an average 1/2400 of an inch in diameter. Now, if a cubic inch of charcoal were cut up into a number of small equal cubes each of whose edges was 1/2400 inch, the total area of their surfaces would be 100 square feet, or taking into account the space occupied by the charcoal itself, it would leave about 73 square feet. The thickness of the liquefied carbonic acid over this area would, then, be about 0.000002 inch.

This harmonizes to a certain extent with Saussure's remark that denser charcoals, that is, charcoals with pores of smaller diameters, and representing a greater surface for condensation, are the greater absorbers. Nevertheless, we must not forget to notice that the affinities between charcoal and different gases are not the same, and that these will seriously modify any results derived from mere geometrical considerations.

THERMAL EVOLUTION AND ABSORPTION OF GASES BY CHARCOAL AT LOW TEMPERATURES.*

Saussure first observed and roughly noted that the absorption of gases by charcoal at the ordinary temperature gave rise to a considerable evolution of heat. The liquid air and hydrogen calorimeters can be easily arranged to afford an exact measure of the quantities of heat thus given up by the condensation of different gases in charcoal. For this purpose a small glass bulb *C*, containing from half a gramme to a gramme of charcoal, has a long narrow tube *C'* attached, so that it can be immersed in the liquid oxygen, or air in the calorimeter *A B*, while still allowing a part of the tube to project above the cork *A*. The calorimeter is then inserted in a large vacuum vessel *H*, containing two or three liters of liquid oxygen or air, as the case may be, and kept in its place by a loose stuffing of cotton wool. In order to dry and cool the entering gas (which, in my experiments, did not exceed 40 cubic centimeters) a little annular space is arranged at *D*, into which liquid air is poured immediately before the experiment begins.

The charcoal, after being placed in the small bulb *C*, is heated to a low red heat, and simultaneously exhausted by a good air-pump, and after all the gas has been removed, the stop-cock *E* is closed. In this condition it is placed in the calorimeter *B*.

The experiment is conducted by connecting the end

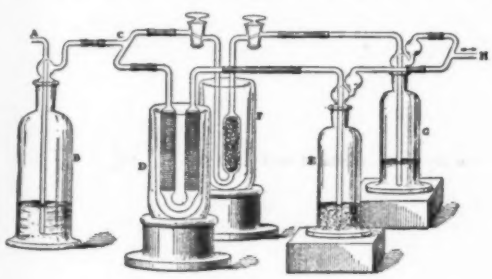


FIG. 4.

of the tube at *E* by means of an india rubber tube with the graduated vessel *F* containing the gas to be examined. When all is ready the stop-cock *E* is opened, so that the gas may rush into the charcoal, and the heat evolved by its absorption distills off the equivalent quantity of liquid air from the calorimeter *B*, which is then received and measured in the vessel *G*.

When we know the constant of the calorimeter—namely, the number of cubic centimeters of gas evaporated by one calorie (about 14.5 cubic centimeters in the present case)—from the readings of the two jars *F* and *G* we find at once the heat evolved in the condensation per unit volume of gas absorbed. After making a few necessary corrections, the results for different gases are as given in the following table:

	I. Volume absorbed at 0° C	II. Volume absorbed at — 185° C.	III. Ratio of II. to I.	IV. Heat evolved in gramme calories by absorption at — 185° C.
Helium	2 c.c.	15 c.c.	7·5	2·0
Hydrogen	4 "	135 "	34·0	9·3
Electrolytic gas	12 "	150 "	12·5	17·0
Argon	12 "	175 "	14·6	25·0
Nitrogen	15 "	155 "	10·3	25·5
Oxygen	18 "	230 "	12·8	34·0
Carbonic oxide	21 "	190 "	9·0	27·5
Carbonic oxide and oxygen	30 "	195 "	6·5	34·5

To render these results comparable, the same specimen of cocoa-nut charcoal was used for them all, and the numbers in the last column are for absorption by one gramme of charcoal. The volumes of the gases absorbed are, both at ordinary and low temperatures, given under standard conditions; namely, 0 deg. C. and 760 millimeters of mercury pressure. If it is desired to know the volumes absorbed at — 185 deg. C., when these volumes are measured at — 185 deg. C. and 760 millimeters pressure, we have only to divide the numbers in column II. by 3.

In each case, a very remarkable increase of absorption takes place at the low temperature. This is shown in column III. It is further remarkable that the increase of absorption diminishes, roughly, as the boiling points of the various gases increase, while column IV. shows a corresponding increase in the quantities of heat evolved.

The general results are seen best when the values of the thermal evolution and the amount of charcoal involved are reduced to molecular volumes of the condensed gas.

Heat Evolution.

Charcoal absorption per Molecular Volume.

	Calories.	Wght. of Charcoal.
Hydrogen	1600	206 grms.
Nitrogen	3686	180 "
Argon	3636	162 "
Oxygen	3744	160 "
Carbonic Oxide	3416	148 "
Carbonic Oxide and Oxygen	3960	144 "
Electrolytic Gas	2414	180 "

Mean $C_{14}M$; limit C_9H_2 and $C_{12}He$.

A comparison of the molecular latent heats of the liquefied gases, hydrogen, nitrogen and oxygen, with the charcoal heat of condensation in each case, is shown in the following table:

	Molecular Latent Heats. (Calories)	Molecular Absorption in Charcoal. (Calories)
Hydrogen	238	1600
Nitrogen	1372	3684
Oxygen	1664	3744

But perhaps the most striking result is the great difference in properties exhibited by helium. While resembling other cases in showing increased absorption at the temperature of liquid air, the absolute amount occluded is about one-tenth that of the other gases at the same temperature, and the quantity of heat evolved is in even a smaller ratio. We must, however, note that the position of helium on the scale of temperature, for these experiments, is quite different from that of the other gases, even hydrogen. For helium is being absorbed at a temperature some fifteen times higher than its boiling point (say 6 deg. abs.), while in the case of hydrogen this is only four and a half times its boiling point (20 deg. abs.). To make a fair comparison, we should take hydrogen at fifteen times its boiling point, which would bring us up to some 27 deg. C., that is, the helium absorption at — 185 deg. C. should preferably be compared with the hydrogen absorption at 0 deg. C. The inference then is, that if we had the absorption of helium at

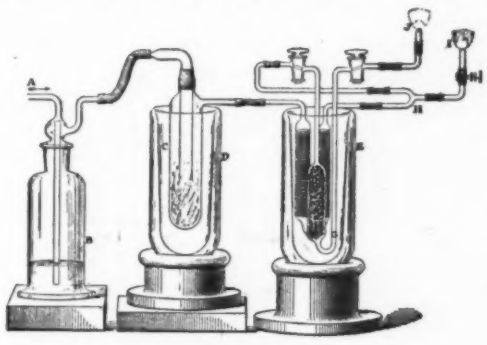


FIG. 5.

25 deg. to 30 deg. absolute, we should find it show a still more remarkable condensation than hydrogen does at 90 deg. abs. (— 183 deg. abs.).

The following experimental results confirm this point of view:

Helium and Hydrogen.

Charcoal Absorption at the Temperatures of Boiling and Solid Hydrogen.

Temperature.	Helium. Vols. of Carbon.	Hydrogen. Vols. of Carbon.
— 185° C. (boiling point of liquid air)	2½	137
— 210° C. (liquid air under exhaustion)	5	180
— 252° C. (boiling point of liquid hydrogen)	160	258
— 256° C. (solid hydrogen)	195	

As the relation between volume and temperature is nearly lineal at the lowest portions of either the hydrogen or helium absorption, we may infer that at the temperature of from 5 deg. to 6 deg. helium would be as freely absorbed by charcoal as hydrogen is at its boiling point, and that in all probability the boiling point of helium is not below 5 deg. abs. This inference is quite legitimate, because good charcoal at the respective boiling points of liquid hydrogen, nitrogen or oxygen, absorbs at atmospheric pressure nearly the same volume of each gas, viz., 260 cubic centimeters per gramme.

It is to be noted that the rate of increase of the helium absorption is three times that of the hydrogen, so that a degree or two makes a large increase in the volume condensed. From these results it seems highly probable that the boiling point of helium is about a fourth that of hydrogen, just as the latter is about one-fourth that of nitrogen.

In column IV. we get the heat evolved by each gas. These values provide us with still further striking results, for the heat developed is, generally, greatly in excess of that required for liquefaction. Thus, for hydrogen, whose latent heat at the boiling point I have recently determined by this calorimeter and found to be 120 gramme calories, the liquefaction of 135 cubic centimeters of this gas would only evolve about 1½ calories, or one-sixth of that evolved by occlusion in charcoal at the boiling point of air. Similarly, if we take 51 gramme calories as the latent heat of oxygen, the liquefaction of 230 cubic centimeters of this gas would produce some 17 calories, or about half of that evolved during occlusion.

SEPARATION OF HIGHLY CONCENTRATED OXYGEN FROM AIR BY CHARCOAL AT LOW TEMPERATURES.

In order to examine the changes taking place in a mixed gas like air during the absorption, a quantity of about 50 grammes of charcoal was after heating and absorption saturated at — 185 deg. in a current of pure dry air—got by passing the air current through a U-tube immersed in liquid air.

For a time the air rushed into the charcoal with great rapidity, and in about 10 minutes between 5 and 6 liters were taken in. A manometer attached to the vessel containing the charcoal showed, on shutting off the air current, that during the early part of the saturation the absorption was so effective as to give practically no measurable mercury pressure. As soon as the absorption was ended, and a current began to pass slowly over the charcoal, the composition of the air leaving the charcoal showed 98 per cent nitrogen. After the current of air had passed for half an hour, the total gas occluded in the charcoal was expelled by taking the vessel in which it had been treated out of the liquid air, and allowing the temperature to rise to 15 deg. C.

The gas, which was rapidly expelled, measured 5.7 liters, and contained 56 per cent of oxygen. If the saturated charcoal before heating was subjected for an hour to the action of an air-pump, capable of giving a steady exhaustion of 5 millimeters, no difference was effected in the oxygen percentage of the evolved gas. The same experiment was repeated with this variation, that, instead of the air current having the pressure of the atmosphere, it was kept below one-tenth of an atmosphere. In this experiment 4.8 liters were expelled on heating up, and the percentage of oxygen was 58. Then, a further repetition was made with an air current supplied at a pressure not exceeding 5 millimeters of mercury. After three hours' treatment, the charcoal, on heating to 15 deg. C., gave 4½ liters of 57 per cent oxygen. From these experiments it follows that the tension of the occluded gases, at the temperature of liquid air, must be very small, and thus the use of low temperatures, combined with charcoal, introduces a new and greatly improved means of getting high vacua, which in the future may be found susceptible of important practical applications. These experiments are quite conclusive as to the practical constancy of the mean composition of the air gases occluded in the charcoal (subject to the conditions aforesaid), and they further show that wide changes in the pressure of the air current have little or no effect in altering the proportions. In another experiment, the vessel containing the saturated charcoal, instead of being allowed to rise rapidly in temperature, was transferred to a vacuum vessel, in which a little air was placed, in order that the temperature might rise slowly, and thereby enable the successive liters of gas given off to be collected separately and analyzed.

This experiment gives the following results:

	Oxygen per cent.
First litre	18·5
Second "	20·6
Third "	53·0
Fourth "	72·0
Fifth "	79·0
Sixth "	84·0

The mean composition of the 6 liters is again 56 per cent oxygen. From the above experiments it follows that one of the most rapid means of extracting a high percentage of oxygen from atmospheric air is to absorb it in charcoal at low temperatures, and thus to expel it either rapidly or slowly by heating the mass of charcoal to the ordinary temperature.

A few experiments have been made using, instead of air, special mixtures of oxygen and nitrogen. Thus it was found that a gas containing 6.5 per cent of oxygen, used in the same manner as in the air occlusion experiments, gave, on heating up the charcoal rapidly to 15 deg. C., 5 liters of gas having the composition of 23 per cent of oxygen. A repetition of the same process with the 23 per cent of oxygen would have raised the percentage about 60 per cent, or a stronger concentration could have been reached by fractionating the gas as it slowly leaves the charcoal on gradually increasing the temperature.

PRODUCTION OF HIGH VACUA AND SPECTROSCOPIC STUDIES. SEPARATION OF GASES LIKE HELIUM, NEON, AND HYDROGEN FROM AIR AND OTHER GAS MIXTURES.*

The high absorption of gases by charcoal suggested an inquiry into the limits of gaseous pressure reached by such means of condensation. With this object, an ordinary spectroscopic sparking tube *A B* was sealed to a narrow tube *C E*, the end of which was blown into a bulb, *D E*, capable of containing a few grammes of cocoanut charcoal. After the charcoal had been freed from gases by heating and exhaustion, and the poles cleared by sparking during this operation, pure and dry gases like oxygen, nitrogen, air, carbonic oxide, hydrogen, neon, and helium, could be admitted at different pressures and the tube with its attached charcoal chamber sealed off.

On placing the charcoal capsule in liquid air, the gas in each case was rapidly absorbed, and the vacuum produced reached the phosphorescent stage, except in the cases of hydrogen, neon, and helium.

A large spectroscopic tube of 1,300 cubic centimeters capacity was sealed to a bulb containing 30 grammes of charcoal. When the tube was filled with air at atmospheric pressure and the charcoal cooled in liquid air, the pressure fell to 50 millimeters of mercury. On refilling the tube with air at the pressure of half an atmosphere, and treating it as before, the exhaustion reached beyond the striæ stage; and a final charge at a quarter of an atmosphere gave a vacuum through which no spark passed. When the experiment was re-

* Proc. Roy. Soc., 1904.

* Proc. Roy. Soc., 1904.

peated with only 1 gramme of charcoal, and an initial pressure of 3 millimeters of mercury, the vacuum just reached the beginning of the phosphorescent stage.

When hydrogen was employed, in order to get a vacuum well up in the striæ stage, either a larger amount of charcoal had to be employed or the initial pressure had to be less than an atmosphere. But, if the liquid air bath was cooled to — 210 deg. C. by exhaustion, the tube just reached the beginning of phosphorescence round the cathodes. With helium there was very slight absorption, but more appreciable results were obtained with neon. Spectroscopic observations made during the condensation of the gas in the charcoal showed the gradual disappearance of the characteristic spectrum of oxygen, nitrogen, and air, as the high vacuum was reached and the discharge passed with great difficulty. In tubes of this kind filled at atmospheric pressure, the F line of hydrogen and the neon yellow could always be seen; but the helium was not seen with any definiteness. As the amount of neon in the air cannot well exceed 1/50000, the spectroscopic test is very delicate.

In order to get the helium spectrum the air in the sparking tube had to be enriched six or seven times. This was attained by the apparatus in Fig. 3. *A B* is the sparking tube, with its small charcoal bulb *C* attached, capable of being sealed off at *G* when required; and *D* and *E* are larger charcoal absorbers placed in vacuum tubes containing liquid air; the whole being attached to a graduated gas-holder, *F*, containing air. A series of glass stop-cocks are attached at the points *H*, *I*, *J*, and *K*, to facilitate manipulation.

In a preliminary experiment to determine the volume of air necessary to bring in the helium lines, 200 cubic centimeters of air were supplied to one of the charcoal vessels *D*, containing 15 grammes of charcoal, from which the residue was passed on to the sparking tube. This tube gave the hydrogen lines C and F, the neon yellow and some of the orange lines, along with the helium yellow and green quite distinctly. Another tube with the residuary gas from a liter of air gave all the helium lines as well as the neon yellow and the hydrogen F; from which we infer that by this means 1/50000 of helium can be detected, so that the test is as delicate for helium as for neon. A third tube, supplied from 3 liters of air, gave the neon and helium spectra and a brilliant ruddy glow discharge.

As 40 to 50 grammes of charcoal can absorb at the temperature of liquid air from 5 to 6 liters of air, it is easy to accumulate rapidly the uncondensed gases in considerable quantities for spectroscopic examination. For this purpose it is convenient to use two charcoal condensers in circuit. After the charcoal in the first one, marked *E* in figure, was saturated, the stop-cock *K* was closed, while *I* and *J* were opened for a short time to allow the less condensable gas in *E* to be sucked into the second condenser *D* along with some portion of air. The condenser *E* was then taken out of the liquid air, rapidly heated to 15 deg. C. to expel the excluded air, and was thus ready to repeat the operation. In this way 50 liters of air can be treated in a short time, supplying sparking tubes showing brilliantly the complete spectra of the volatile constituents of the air.

The results derived from the treatment of Bath gas in this way are interesting. This gas, consisting mainly of nitrogen and 1/1000 part helium, when subjected to the action of the charcoal condenser in liquid air, gives no high vacuum. All the nitrogen and any other constituents are absorbed, and a spectrum of helium and hydrogen showing much less neon than exists in the volatile residue from atmospheric air is the result. A sample of argon prepared from Bath gas treated in the same way, gives a tube showing the helium and neon spectrum; and one prepared from atmospheric air gives a similar result, but the helium spectrum is the stronger in the Bath argon, whereas with the atmospheric argon the neon spectrum is the most pronounced.

ILLUSTRATIONS OF VARIOUS APPLICATIONS OF CHARCOAL IN EXPERIMENTAL INVESTIGATIONS.

The gaseous products from minerals containing helium, hydrogen, etc., also the products from radium compounds, may be treated by the charcoal method. As an example I have applied this method to the crude gases got by heating the mineral fergusonite. During the cooling of the charcoal the nitrogen and hydrogen spectra were marked, but in a short time nothing could be seen but the lines of hydrogen and helium. It is needless to say that the charcoal method of exhaustion can be applied to the manufacture of incandescent lamps and Röntgen radiation tubes, and that the method can be conveniently employed to produce and maintain high vacuum for the purpose of distilling bodies under low pressures. Many experiments with the radiometer can be carried out by the use of the charcoal method of exhaustion. If a charcoal capsule is sealed to the bulb of a radiometer full of air under relatively high pressure, on directing a beam of light on the vanes of the radiometer they remain at rest, showing that the density of the air is too great for motion to take place. When, however, the charcoal capsule is immersed in a vessel containing liquid air, the vanes immediately commence a rapid rotation. On removing this liquid air bath their motion slackens, and finally they come to rest as the charcoal returns to the temperature of the room.

It is known that dry phosphorus does not enter into chemical combination with pure oxygen at ordinary temperature and pressure. A bulb of from 100 to 200 cubic centimeters filled with pure oxygen, having a side tube sealed on of 2 millimeters cross section containing fused phosphorus, the whole being connected by means of a quill tube to a charcoal capsule, containing in part also a good layer of phosphoric anhydride, and the latter immersed in liquid air, the charcoal gradually absorbs the oxygen, and at a particular pressure the oxidation of the phosphorus vapor begins, and is revealed in the form of a phosphorescent glow, filling the whole of the glass bulb, which continues until the oxygen pressure gets too low. On removing the liquid air bath, at a certain stage of the increasing pressure of oxygen, the bulb again becomes a glowing mass of phosphorescence, which wanes and disappears as the normal pressure is reached. This experiment may be repeated a great many times provided the phosphorus in the small side tubes does not get into active combustion, which can always be avoided by a slight cooling. Such bulbs can be kept in the dark for months, and at the end of the time are quite active when cooled as described. A manometer attached to the side of the oxygen bulb shows that the oxygen pressure at the moment phosphorescence begins is only a fraction of a millimeter of mercury. From these results it appears that perfectly dry oxygen below 1 millimeter pressure combines with phosphorus.

The following experiment proving the absorption of carbonic acid, at a small partial pressure, by charcoal is very striking. A continuous stream of ordinary atmospheric air, containing three volumes of carbonic acid in ten thousand, is made to enter the apparatus, Fig. 4, at *A* and leave at *H*. It first passes through the jar *B*, which contains some strong sulphuric acid, by which it is thoroughly dried. On leaving *B* the stream of air is divided at *C* into two portions, one of which passes through the jars *D*, *E*, the other through the jars *F*, *G*, the two finally uniting and passing out at *H*. *D* and *F* are vacuum vessels containing solid carbonic acid, which maintains a temperature of — 78 deg. C. The air passes through a U-tube in *D*, the arms of which are filled with coils of copper gauze to insure the complete reduction of its temperature to — 78 deg. C. It next passes through the jar *E*, containing some baryta water, which absorbs the carbonic acid remaining in it, before it emerges at *H*. The other stream of air passes in like manner through a U-tube in *F*, in one arm of which is a quantity of dry charcoal in small lumps; thence, after bubbling through some baryta water in the jar *G*, it passes to *H*, where it escapes. Now, the streams of air entering *D* and *F* are in exactly the same state, but while *E* shows by the milky deposit taking place that the one stream is still fully charged with carbonic acid after being thoroughly cooled to — 78 deg. C. in *D*, *G* shows by remaining permanently clear that a similar cooling of air to — 78 deg. C. in the presence of charcoal causes, for a time, complete absorption of the carbonic acid from the air, and this goes on until the charcoal absorbs about 1 per cent of its weight of carbonic acid.

The absorptive power of charcoal for hydro-carbons is shown in a similar manner by the following experiment: common coal gas enters the apparatus in Fig. 5 by the tube at *A*, and after being dried by bubbling through strong sulphuric acid in the jar *B*, has the less volatile gases condensed by passing through a vessel *C* cooled with carbonic acid snow, isolated in the vacuum vessel *D*. The gas is further purified by percolating through the two copper coils contained in the arms of the U-tube *F F*, immersed also in solid carbonic acid in the vacuum vessel *E*, after which it passes on to *H*, where its path is bifurcated, one branch leading to *I*, where the issuing gas is lighted, while by the other branch the purified gas passes over charcoal in the U-tube *G*, also at the temperature of solid carbonic acid, before proceeding to *J*, where it in turn is lighted. The difference between the two flames is very noticeable, that at *I* being quite luminous, while the other at *J* is non-luminous, like a Bunsen flame. The explanation is, that the charcoal at the temperature of — 78 deg. C. completely absorbs for a time all the hydrocarbons, such as marsh gas and ethylene, upon which the luminosity of the flame of coal gas depends, leaving practically carbonic oxide and hydrogen.

This preliminary investigation suggests many fields for further inquiry.

[Continued from SUPPLEMENT No. 1599, page 25027.]

TINNING.—IV.

TINNING OF COPPER AND BRASS.

AMONG the various kinds of tinning, one of the most important is the tinning of copper and brass, since through the protection afforded by the tin these metals can be used for culinary purposes, which would otherwise be impossible, in many cases, on account of their poisonous qualities. The tinning can be done with melted tin, or by the chemical process called blanching, which is employed especially for small articles.

Copper and brass can be kept bright without much difficulty, and articles which are to be tinned on the inside are usually only scoured. Or a simple way of making kettles, for example, clean, is to fill them with water, add a little nitric acid and hydrochloric acid, and let them stand for some hours, until the surface has become bright. Then rinse several times in clear water. The vessels, having been made clean and bright, are heated over a coal fire to the melting point of tin; the tin is poured in, powdered ammonium chloride (sal ammoniac) scattered over it, and it is rubbed in with bunches of tow. Another way is to dip the articles into a kettle of melted tin, with a protective cover of grease or zinc chloride. The tin will adhere only to clean, bright surfaces.

For tinning copper of brass utensils which are to be used in cooking, or by dyers or apothecaries, only the very purest tin should be used, and it must be tested for contents of lead. Besides the danger from lead, tin containing it will not adhere so well to copper as if pure.

Small copper and brass articles are scoured with sand and water, or pickled with acids; then heated in earthen vessels to a temperature above the melting point of tin. The melted tin is poured into the kettle, sal ammoniac (ammonium chloride) thrown in, and the kettle is lifted off the fire and shaken hard, so that the tin will reach all parts of the articles. They are then put into sieves and cooled with water. But the "blanching" process, as before observed, is usually preferred for small objects.

In tinning kettles and other utensils which will frequently be scoured when in use, a liberal application of tin is to be recommended. Otherwise, the coating will soon become impaired, and the article will have to be re-tinned.

BLANCHING.

This operation is performed in different ways. The simplest method is blanching in tartar. Small articles, brass pins, for example, are first scoured bright with sand and water, in a rotating barrel, then kept in a boiling solution of tartar, with granulated tin, for an hour or two, removed, rinsed with water, and dried in sawdust or in the air. One part of tartar is generally used to twenty-four of water, and once and a half the weight of the pins in tin. The tin coating obtained in this way looks well, but is not very durable.

More durable coatings are made by the use of potassium stannate. This is prepared as follows: Melted tin is granulated by slow pouring into water. The grains are put into a glass or porcelain vessel, and red nitric acid poured over them. Tin oxide, a white powder, will be formed, with violent foaming of the liquid, and evolution of brownish red fumes. It is injurious to breathe these fumes, and the operation should be carried on beneath a chimney with a good draught. The tin oxide is separated from the tin which remains unchanged, by washing with water, and dried. The dry powder is mixed with pure potash in the proportion of 3 parts to 4, melted in an iron kettle and the molten mass poured out upon a stone. This is potassium stannate, to be dissolved in boiling water. A somewhat simpler method of procuring it is to add ammonia to a solution of tin-salt in water, until there is no longer any precipitation; take the precipitate off on to a linen cloth, wash several times with water, boil the residue, which consists of hydrated oxide of tin, with strong potash lye, and dilute the solution of potassium stannate thus obtained with water.

Pins are tinned by dipping them into this liquid on a sieve; larger articles are laid in and stirred around with a rod of tin. The temperature of the liquid should be between 50 deg. and 55 deg. C. (122 deg. to 131 deg. F.).

It is well to coat over large brass or bronze articles with copper before tinning. This is done by wrapping them around with iron wire, and immersing them in dilute sulphuric or hydrochloric acid.

To give a light surface coating of tin to copper or brass, or iron, the articles may be dipped into a solution of tin-salt, in which granulated tin has been lying for some time; dust them over with powdered zinc, rub with a woolen rag, and repeat the process until they appear to be tinned.

STANNIC CHLORIDE.

Stannic chloride, or tin-salt, is a chemical compound which is often brought into requisition in the process of tinning. It is prepared simply by dissolving tin in hydrochloric acid, and evaporating the solution to crystallization. Tin-salt is extensively used in dyeing, and is manufactured in large quantities in chemical establishments. It is better to buy it than to attempt its manufacture on a small scale.

Commercial tin-salt is often only partially soluble in water, leaving a white residue, consisting of a basic compound. But this can be dissolved by adding a few drops of hydrochloric acid.

TINNING OF LEAD.

The tinning of lead is of especial importance for lead pipes and vessels which are to hold water. In the case of cast lead pipes, the tin is sometimes poured into them while they are still hot, and distributed over the surface by rubbing with tow rolled in colophony (rosin) or moistened in turpentine. The outside of the pipe is similarly treated. Sometimes the hot pipes are coated over with rosin, inside and out, and then put through a tin bath. Both these methods, however, are somewhat antiquated, and the customary way at the present time is to plate the lead with pure tin by the following process. Within an iron cylinder, into the bottom of which is fitted the piston of a hydraulic press, is cast a leaden cylinder. The iron core is removed, and replaced by one of less diameter, and strongly heated tin poured into the free space. Over the top of the iron cylinder is fastened a plate with a circular opening, which fixes the outer diameter of the pipe, while the iron core fixes the inner diameter. The hydraulic press being set in motion, a lead pipe coated on the inside with tin is forced out through the opening in the plate.

Tin-plated lead pipes can also be made by pouring melted lead into a rapidly revolving mold, and pouring in melted tin after the lead has hardened. The centrifugal force developed by the rapid motion of the form throws the tin against the sides of the pipe. But the

first method is preferable, and almost all lead pipe is made in this way.

For tinning sheets of lead, plating is also the best method. Here a table is employed, having a horizontal, perfectly smooth iron top, with a raised edge, to prevent the metal from running off. The lead is poured out upon the table, and covered with grease to prevent oxidation. After it has cooled, melted tin is poured over it, so hot that the surface of the lead is melted again, and intimately united with the tin. When the sheet is cool enough, it is turned over, and plated on the other side. It can be rolled out very thin without injury to the tin coating, and is suitable for lining boxes for crackers, chocolate, tea, tobacco, confectionery, etc.

If sheets of lead are to receive only a superficial tinning, they are heated quite hot, strewn over with powdered colophony, and melted tin is rubbed on with bunches of tow. It is well to have the coating quite thick, as it will be made thinner by rolling.

TINNING OF ZINC.

It is quite an easy matter to tin zinc, as tin adheres well to this metal. The articles are first pickled clean and bright with sulphuric or hydrochloric acid, then dipped in melted tin, covered with a layer of grease. Sheets of zinc are tinned like sheet iron, by the English method, which is to dip the sheet, pickled and heated, into a tin bath, with a cover of tallow, and then into very hot melted tallow alone, in order that it may cool slowly and evenly. Large sheets of zinc may be tinned by laying them upon an iron plate, heated from underneath, strewing them over with powdered colophony or pouring on melted tallow, and then rubbing in melted tin with tow, as before described. Heavy zinc plate may be given a durable plating in the same way that lead is plated, except that the zinc plate is not usually cast upon the same table where the tinning is done, but is cast, and rolled once or twice, then laid upon this table and warmed.

Good tinned sheet zinc is excellently well adapted to making the most durable roofing, gutters, water pipes, etc., and deserves more extensive use than it has yet had.

Zinc articles can be very simply and easily tinned as follows:' Prepare a mixture of 2 parts of tin chloride, 2 of purified tartar, 4 of water at 75 deg. C. (167 deg. F.), and enough of the finest sand to make a pulpy mass. Apply this with a sponge or brush to the articles. The tin coating will at first be dull gray, but rubbing with clay and sand will bring out a fine tin luster.

Tin can be deposited upon other metals in any desired thickness by the process of electro-plating, and this method is now frequently employed. It is easy, and the plating is durable.

EXTRACTION OF TIN FROM SCRAP TIN.

In working tin plate, there is always considerable waste, from which the pure tin, amounting to from 3 to 5 per cent, can be extracted. This is of considerable value, but the method of extraction must be as simple and cheap as possible in order to make the work profitable. The tin may be obtained in a pure state, or as tin-salt, which commands a good price on account of its extensive use by dyers and cloth-printers, or also in the form of sodium stannate.

The simplest method of extracting the tin is by centrifugal force. The scraps are placed in a sheet iron drum, perforated like a sieve, and heated to the melting point of tin; by the rapid revolution the tin is obtained in drops. The principle of this method is good, but in practice two disadvantages have to be contended with, namely, that all the tin is not extracted, and that it is so alloyed with iron as to be fit only for a first tinning.

In working up scrap tin by the wet method, either the tin or the iron may be dissolved. If the ferric salt can be profitably utilized, the latter method is to be recommended; if not, it is too expensive.

To extract the tin in an almost chemically pure state, a wooden vat is filled with scrap tin, dilute hydrochloric acid is poured in, and it is left for a while. The tin will dissolve in the acid, but the iron will not, as long as there is any tin left to dissolve. The liquid is drawn off at the bottom of the vat, filtered, and sheet zinc is immersed in it. The tin will separate in a spongy mass, which is then melted under a cover of tallow. The solution of zinc chloride which remains can be evaporated and used as a cover when melting tin. The pieces of iron are disposed of to foundries.

If the iron is to be dissolved, the scraps are placed in a leaden kettle, concentrated sulphuric acid is poured over them, and they are heated to 100 deg. C. (212 deg. F.). The iron dissolves and the tin is deposited on the bottom of the kettle. If sulphuric and nitric acids are used together, the tin will also be dissolved, and can be precipitated by means of introducing fragments of iron into the solution.

If a very large quantity of scrap tin is at disposal, it may be boiled out in water containing hydrochloric and nitric acids and with the aid of steam, and the tin precipitated by zinc. The nitric acid hastens the solution of the tin.

Donath and F. Müllner state that tin can be extracted from scraps at ordinary temperatures by heating 100 parts by weight in a fluid consisting of 20 parts of crude hydrochloric acid, 2 of concentrated nitric acid, and 20 of water.

Attempts have been made to concentrate the very volatile, water-free tin chloride by heating the scraps with chlorine gas, but the product is usually very impure, mixed with ferric chloride.

There are a great number of methods of extracting the tin in the form of tin chloride or of sodium stannate. The tin chloride can be utilized in dyeing and printing establishments, and the sodium stannate can be used in tinning by the wet method.

If litharge, or lead oxide, is treated with caustic soda lye, it will dissolve in this; if scraps of tin plate are heated with the solution, sodium stannate is formed, and remains in solution, while metallic lead is deposited.

If the scraps are put into a vat, and this filled with soda lye, the lye let off after half an hour, and the vat filled again after another half hour, the tin can be oxidized to tin oxide, or stannic acid, by the action of the air and the caustic soda, and thus brought into solution. After a while, the pieces of iron will be entirely free from tin, and the soda lye will have become a solution of sodium stannate.

There are still other methods of extraction, some very ingenious. Most of them, however, are very complicated, and suited only to chemical establishments. For the practical workman, who desires to extract a certain quantity of tin from scraps of plate, one of the methods described will prove the best. That by which the scraps are heated with hydrochloric acid and the tin obtained by precipitation with zinc, is especially recommended.

TINNING WITH TIN AMALGAM.

Small iron articles, pins, for example, can be coated with tin amalgam by melting this under water, immersing the articles, well pickled, and heating them for a while. This method, however, is rather expensive, and has no especial advantage.—Translated from Friedrich Hartmann's "Das Verzinnen, Verzinken, Vernickeln, Verstählen," etc.

OUTPUT OF ELECTRIC GENERATORS.

VARIOUS factors influence the output of electric power which can be obtained from an electric generator of given construction. Assuming always that there is adequate mechanical power available to drive it, and that the speed can be adjusted to the most favorable value, the normal output is limited in several different directions. There are, as everyone knows, two factors in electrical power—current and voltage. If the voltage is fixed, the output is proportional to the current. We may consider separately the limitations of these two factors.

The current that can be drawn from the machine at the working voltage is limited (*a*) by the heating of the armature or other part of the machine; (*b*) by the reaction of the armature interfering with the voltage of the machine; (*c*) in the case of continuous current generators by the difficulty of sparkless collection of the current. On the other hand, the voltage of the machine is limited by other considerations; (*d*) the speed at which the armature is driven; (*e*) the magnetism provided by the field-magnets; (*f*) the adequacy of the insulation of the conductors. Besides these limitations which affect the two factors separately, there is a limitation due to them jointly, namely, (*g*) the adequacy of the mechanical construction of the armature, its mounting, and its shaft to withstand the application of the torque, when running at the actual speed. There are yet two other limitations to be considered, namely, (*h*) the prescription of some particular efficiency, and (*i*) the capacity to endure a temporary overload of some prescribed amount for some prescribed duration. The former of these is practically bound up with the limitation of the temperature rise, since any machine which has a low efficiency is bound to evolve as heat the energy which it wastes; and the latter is more or less involved in the compliance with the requirements at normal load and in the provision of ample margins of safety.

The recommendations of the Engineering Standards Committee define the conditions that shall govern the rating of the normal output of generators for continuous, as distinguished from intermittent, employment, as follows: "The output of generators (and motors) for continuous working shall be defined as the output at which they can work continuously for six hours and conform to the prescribed tests." No detailed regulations as to tests have yet been issued, pending further investigations as to the same limits of temperature rise that are permissible. If, following the general lines of the American and German rules for rating, we assume 50 deg. C. as the maximum rise in continuous working, and an overload capacity of 25 per cent for not more than two hours, we shall probably not be far from the ultimate rules to be laid down by the committee. The Standards Committee has also laid down for alternators the additional rules that their voltage curves shall, under all working conditions, be as near as possible a sinecurve, and that they shall not have a greater percentage pressure-rise (from full-load to no-load), with same speed and excitation, than 6 per cent on a non-inductive load, nor more than 20 per cent on an inductive load having a power-factor of 0.8.

Let it be then assumed that by rules such as these the proper rating of any generator can be arrived at, the questions immediately before us are in what relation does the normal performance of a machine, that is, its rated output, stand to the design of the machine and ultimately to its cost, and in what way are these affected by the engine speed.

Manufacturers are naturally desirous of producing as cheaply as possible the machines that are to fulfill the required specification. The prime cost of materials, iron, steel, copper and mica or other insulating material, and the cost of labor affect the design to be adopted. For of two designs for the same specification, one may require more material, the other demand more labor; and it is quite conceivable that one design might be right for a manufacturer in a country where labor is dear and material cheap, and a different design to be better in another country where labor is cheap and material dear.—Prof. Sylvanus Thompson in the Journal of the Society of Arts.

GREEK JEWELRY.*

THE Metropolitan Museum of Art recently purchased a number of pieces of ancient Greek jewelry which are of extraordinary beauty and importance, and which have an added interest from the fact that they are all said to have been found in the same grave. These are now on exhibition in the Gold Room. They include a diadem, a necklace, a pair of earrings, a finger ring, seven rosettes in the form of small flowers, and nineteen beads from a necklace, all of them being of the pure yellow gold which was customarily used by the Greeks for their coins and for the better class of their jewelry.

Technical characteristics both of the design and the execution make it possible to date these in the fourth century B. C., and probably not later than the middle of the century. They therefore represent the art of the Greek goldsmiths at the highest stage of its development, and they do this not unworthily. For, while none of them (with the possible exception of the rosettes) is unique in the strict sense of the word, yet all exhibit a perfection of workmanship which is not surpassed by similar examples in any other collection; and one has only to examine them carefully to understand why the Greek women, with the keen instinct for beauty which distinguished their race, should have preferred specimens of such delicate craftsmanship for their personal adornment, rather than the mere glitter of precious stones.

The diadem consists of a very thin plate of gold, 14½ inches long and 2⅛ inches wide at the point in the middle (0.368 × 0.06 meter). Its decorations are entirely of *repoussé* work, hammered into low but carefully modeled reliefs. In the middle the youthful Dionysos and Ariadne are sitting back to back, their faces turned toward each other. Each holds a long thyrsos—the staff with a pine cone at the top, which was the emblem of Dionysos and his followers. Their seat is a conventional design of akanthos leaves, from the center of which rises a large flower. From this group a series of large scrolls runs out to either end of the diadem, terminating in the conventionalized honeysuckle or "palmette" pattern; and between the scrolls are small female figures, seated on the stalk of the vine from which the scrolls spring, all facing toward the center. These little figures, of which there are five on each side, are modeled with the greatest care as to details, no two being quite alike, even in their features. From their occupation there would be no hesitation in calling them Muses were there less than ten; and probably they were in fact intended for Muses, each being regarded as a duplicate of the corresponding figure on the other side, with which it balances exactly in pose and action. On each side the first is playing upon the small Greek harp called the *trigonon*, the second holds a pair of pipes, the third is playing on a lyre, the fourth is singing from a scroll which she holds in both hands, and the fifth is playing on a long instrument somewhat like a lute, which has been identified with the *psalterium*.† The combination of these figures with the scrolls surrounding them is gracefully arranged so as to form an uninterrupted design, and the artist has heightened the charm of his composition by introducing minor features, such as the flowers among the scrolls and the three birds on the ground, while on the flowers nearest Dionysos and Ariadne he has placed two grasshoppers.‡

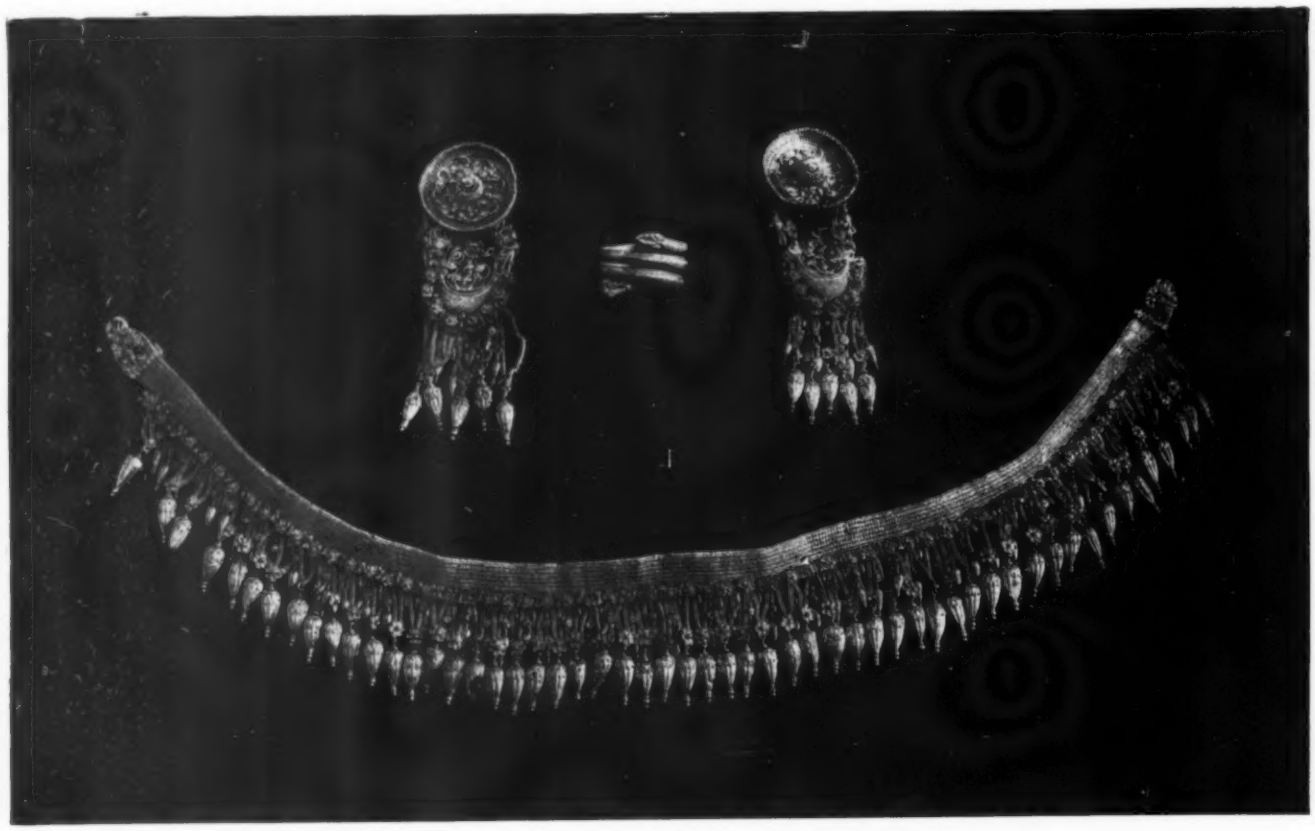
The necklace is of a type which is not uncommon in Greek jewelry, consisting of a closely woven braid of fine gold wire, from which pendants are suspended by intertwining chains, with rosettes at the points of attachment. The examples of this type vary considerably both in elaborateness of the design and fineness of execution; but it may safely be said that none of those hitherto discovered surpasses this in either respect. It has three rows of pendants, all of which are of the usual amphora shape, pointed at the bottom. Those of the upper row are very small, and linked directly to the ornaments below the braid; those of the middle row are somewhat larger, and are suspended by short chains, with a tiny disk at the junction of each chain and pendant; but those of the lowest row are considerably larger and more elaborate than either. In this row each pendant is hung by two chains, and the chains are fastened by rosettes both to the pendant and to the braid above. Perhaps there is no better means of appreciating the exquisite workmanship of the necklace than by studying these rosettes, especially the row along the bottom of the braid. It will be seen that each is double, that is, it consists of a smaller, five-petaled flower placed over a larger one, both wrought with the utmost delicacy; yet tiny as these flowers are, and thickly as they are massed together, every petal of every flower has a fine, twisted wire running around its edge, and we must remember that this wire was not part of the surface, but had to be soldered to it. Originally, too, the petals were prob-

* Bulletin of the Metropolitan Museum of Art

† See Fougères in the Bulletin de Correspondance Hellénique, 1888, p. 119, note 2.

‡ A diadem of somewhat similar character and decorations, though the latter are less beautifully composed, was formerly in the possession of Mr. Frank Calvert at Dardanelles, and is published in the Archäologische Zeitung for 1884, p. 94. The authorities of the museum would be glad to know in what collection this is at present.

ably enameled with bright colors, though these have disappeared. Still finer than the flowers, however, and so small that they can hardly be recognized without a strong glass, are the fore parts of winged griffins which alternate with the rosettes in this row, and from which the upper pendants are hung. In the general effect these count for so little, in proportion to the work expended upon them, that we might wonder at its having been thought worth while to introduce such a minute detail, did we not recognize in them a characteristic example of the Greek craftsman's love of his work for its own sake. It should be noted also that these tiny griffins are modeled by hand, not stamped or molded; and finally, attention should be called to the beauty of the design and execution of the two clasps, as well as to the remarkable preservation of the jewel as a whole.



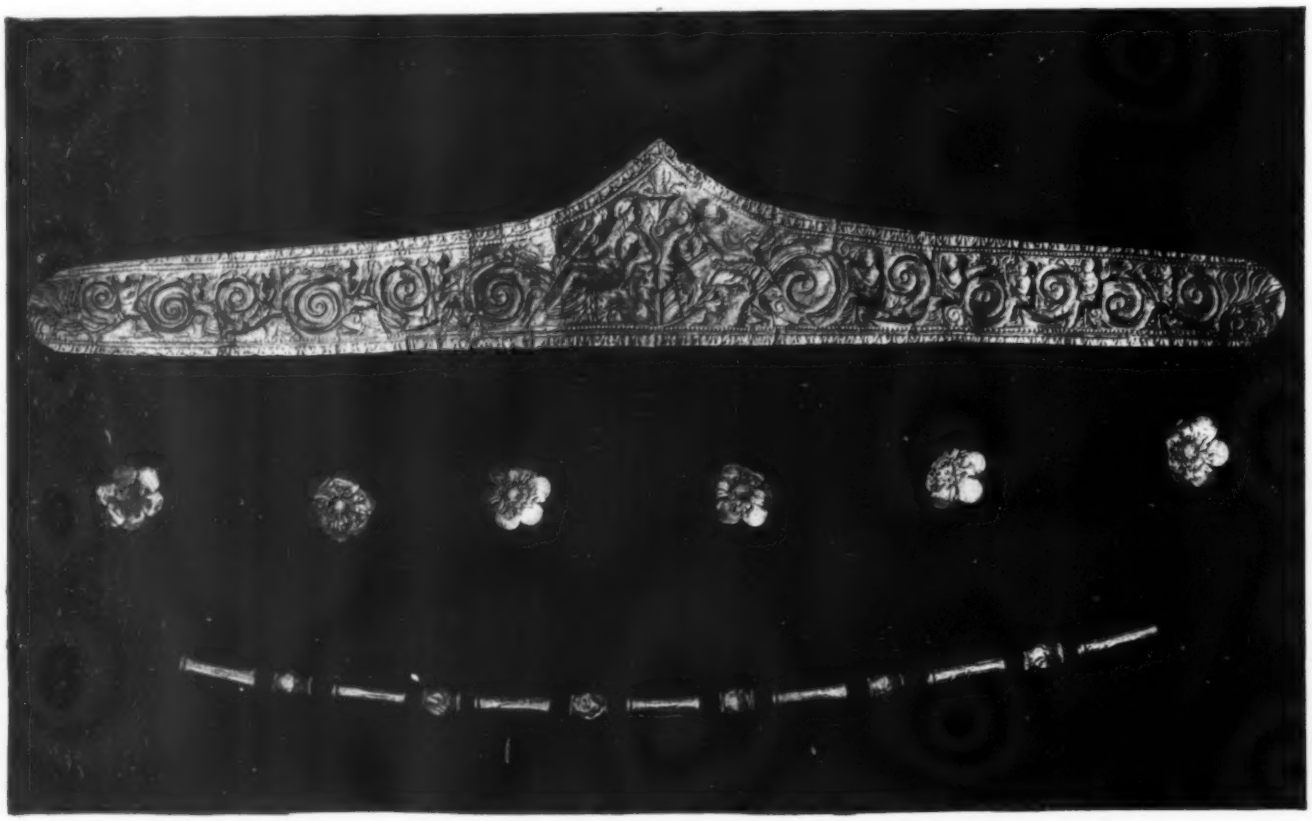
GREEK NECKLACE WITH PENDANTS AND EARRINGS.

The length of the necklace is 12⅝ inches (0.323 meter). It is therefore too short to have been worn loosely, and must have been fastened close around the neck, like a collar.*

The earrings, like the necklace, belong to a type which is not unfamiliar, and like the necklace they rank with the finest examples of their type. The length of each is slightly less than three inches (0.074 meter). The design consists of three parts. At the top is a disk, decorated with an elaborate rosette in filigree; from this is suspended a crescent, convex in section, and from this crescent hang three rows of pendants like those of the necklace, also with the double rosettes and the winged griffins where they are attached. It is unnecessary to dwell again upon the beauties of these details, but the middle portion cannot be passed over, as it displays the most delicate and elaborate workmanship to be found in any of these jewels. The crescent is attached to the disk above it by two hooks or hinges, which are masked by floral designs, and at the side of each stands a figure of Eros (Cupid), represented as a slender boy with large wings, just as he is in the larger works of art of the same period, in distinction to the chubby, short-winged infant whom we find in later Greek and Roman art. The floral ornament is carried across from one side to the other, forming a sort of bower, in the midst of which is seated a Muse playing upon a lyre, this minute figure being modeled in full round. The crescent itself is covered with globules of infinitesimal size, which are arranged in groups of four, with marvelous regularity of spacing, and with just enough distance between the groups to give more variety to the surface than would have been possible had they been simply massed together.*

The other objects do not call for detailed mention, as they are of less importance, and may be easily appreciated from the illustrations. The flowers show much of the skill of the larger pieces, and are modeled with unusual realism for Greek work of this kind, pistils and stamens being rendered carefully and closely after nature.

The necklace and earrings have been cleaned and repaired by Messrs. Tiffany & Co., but there are no restorations.



GREEK JEWELRY RECENTLY PURCHASED BY THE METROPOLITAN MUSEUM OF ART.

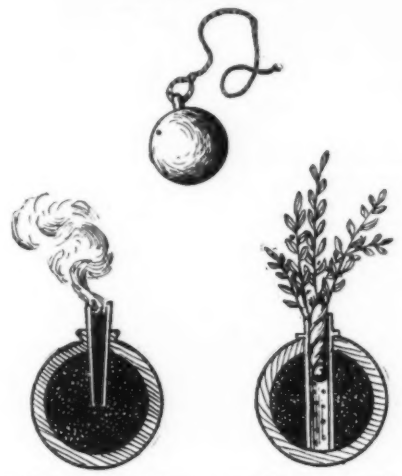
* The design of this necklace is almost identical with that of one in the Hermitage at St. Petersburg, which was part of a rich discovery in a grave on the site of Theodosia, in the Crimea, published in the Antiquités du Bosphore Cimmérien, pl. XIIa, No. 4 (see Reinach' edition, p. 53). Included in the same discovery, and published on the same plate, are a pair of wonderful earrings, and a special finger ring, which are similar in design to those here described.

* For Greek earrings of this type see Karl Hadaczek, Der Obrschmuck der Griechen und Etrusker, Vienna, 1903. According to him and to others the most beautiful example is that from Theodosia referred to in the preceding note, which is very like ours, except that the center is occupied by a quadriga instead of the figure of the Muse.

GRENADES AND GRENADIERS.

ONE of the most striking points about the determined assaults on Port Arthur by the Japanese and the stubborn and heroic defense of that city by the Russians is the immense variety of warlike appliances that have been called into play by both sides. Some of these, such as electrically charged wire entanglements, represent the *dernier cri* in military art, while others, such as the noxious and poisonous-smelling compositions thrown into the Russian trenches by the Japanese, their bamboo mortars, and the armor shields carried by their pioneers when endeavoring to cut through the entanglements surrounding the forts of the defenders, carry one's thoughts back to quite medieval ages. Hand grenades, which have been practically out of date for a century, have been employed by both sides so extensively that it seems possible that their use and manipulation may enter into the general curriculum of the soldier's training in our own and other modern European armies. Time was when these deadly little missiles were carried by a number of the biggest and strongest soldiers in every infantry regiment, and for many years after they had fallen into disuse the grenadier company, composed of

Grenade with loop and cord.



Ordinary Grenade with fuse of slow-burning composition.

Grenade of 1650 with twigs and slow match.

such men and wearing a distinctive uniform, formed the right company in every battalion, just as the light infantry company, containing the smallest and smartest scouts and skirmishers in the corps, formed the left one.

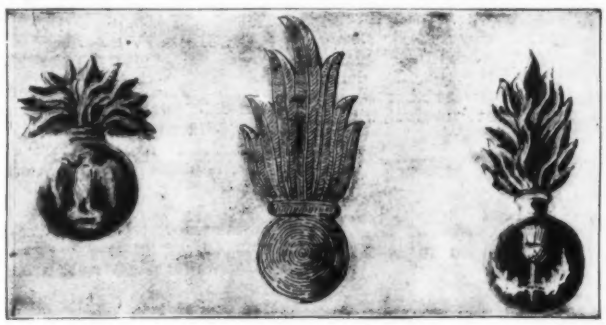
Nowadays the only grenadiers are special regiments, such as our own grenadier guards and other similar *corps-d'élite* in the German, Russian, Belgian, and other armies on the Continent. But as a badge, the grenade is still one of the most favorite ones in the world. With us it is carried by the grenadiers, fusileers, Scots Greys, engineers, artillery, and marine artillery; it is almost universal in the French army, and is far from infrequent in the armies of Germany, Italy, and Russia.

The word "grenade" is a French word, meaning pomegranate, the little hand-thrown shells being about the size of that fruit—about 2½ to 3 inches in diameter. The precise date that these weapons were first invented seems uncertain, but it appears that they were made in large quantities at Arles in 1536. They were used at the siege of Rouen in 1562, and in that of

GRENADIER OF THE 2D QUEEN'S REGIMENT, 1687.

Famagusta, in Cyprus, nine years later. At this period and for a long time afterward, though they seem to have been in pretty extensive use, there were no specially trained companies or regiments of grenadiers. Then, as now, they were specially intended to be used in trenches, at barricades, and at close quarters in narrow streets and passes. Nor was their use confined to the land service, as in December, 1652, we find the ordnance officials of the navy asking for "five thousand hand grenades at 2s. 6d. each." According to one description, the grenade at this epoch had a fuse which consisted of a wooden tube whose sides were perforated with numerous small holes. At the top of this tube was a piece of lighted slow-match with a bullet attached to its lower end. When it struck the ground the weight of the bullet would drag the lighted match into the perforated tube, and so ignite the powder and burst the grenade. To make the missile strike right side uppermost, so that the bullet would drag the match downward, the opening at the top had a bunch of box twigs attached, which acted in the same way as the feathers of an arrow or the stick of a rocket. Possibly the long pyramidal projection which is seen at the top of the grenade worn as a badge by some regiments represents this bunch of leaves, though it is generally supposed to represent the flame issuing from the fuse.

GRENADIER CAP WORN 1765-1800.



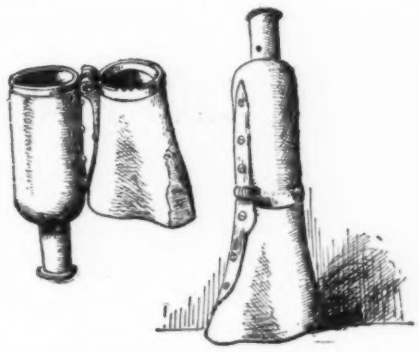
1. Royal Fusileers. 2. Royal Artillery. 3. Royal Scots Fusileers.

VARIOUS TYPES OF GRENADE BADGES IN THE BRITISH ARMY.

In some cases this is very much larger and more spreading, and without doubt represents flames—much more flame than would be seen in reality. The French were the first to establish regular grenadiers, in the year 1667, when four men were selected in each company of the "King's Regiment" for training in the use of hand grenades. In 1670 these men were formed

A GRENADIER OF 1745.

Flintlock Musketoon or hand-mortar for discharging hand-grenades, with support.



A "tinker's" Mortar from Grosse's Military Antiquities, 1801.

"An uncommon engine supposed to be a tinker's mortar, which being fixed in a stick was used for throwing grenades."

FRENCH GRENADIER. FROM A PRINT PUBLISHED IN 1696.

GRENADES AND GRENADIERS.

into a grenadier company, which was commanded by M. de Riotor, who thus enjoys the honor of being the first grenadier officer on record. In the same year thirty of the most senior regiments in the French service were also provided with grenadier companies. Eight years later we followed suit in this country, as is recorded in "Evelyn's Diary." He says: "29 June, 1678.—Now were brought into service a new sort of soldiers called 'grenadiers,' who were dextrous in flinging hand grenades, every one having a pouch full. They had furred caps with coped crowns like Janissaries, which made them look very fierce; and some had long hoods hanging down behind, as we picture fools, their clothing likewise piebald—red and yellow." Then, and for many years after, grenadiers carried,

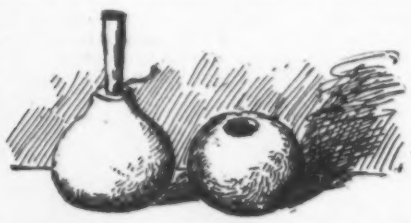
Manner of holding the grenade in the British service, 1847.
(Land service grenades, 1 lb. 13 oz. Naval service grenades, 4 lbs. 2 oz.)

besides their bag of grenades, axes, firelocks, dagger bayonets, and swords. After throwing their missiles they were drilled to rush upon the enemy's defenses, ax in hand, on the order "Fall on." At first, our grenadiers wore a certain amount of armor—breastplates, at any rate. At the storming of Aughrim, in 1691, it is related that "the forlorn hope consisted of sixty grenadiers in breastplates." This must have somewhat impeded their activity, and in France, at any rate, the grenadiers wore a very easy-fitting costume. In the description which accompanies the plate it explains: "The figure B shows the position in which those throwing the grenade should stand, so that by a single movement and in an instant, turning the back to the place at which it is intended to throw it, it can be done more promptly, for in any other posture at least two or three times as much time is required to throw it, which

Grenade of common green bottle glass as used by Spaniards, 1847.
(External diameter, 2⅝ inches. Weight, 10¼ oz.)

might be very hazardous to the grenadier." Hand grenades were employed in conjunction with an inflammatory mixture, the two being placed together in an earthenware pot covered with parchment, like a jam-pot, and provided with a fuse and a rope handle. This was then thrown into the enemy's works, the pot broke, the composition blazed up, perhaps started a conflagration, and at any rate igniting the fuse of the grenade, which of course exploded.

The fur caps worn by our first grenadiers before long gave place to cloth ones with a shorter hood. The latter adornment had quite disappeared by 1715, but the front of the cap, which was generally of the color of the regimental facings, was handsomely embroidered. With slight changes this high miter-shaped cloth cap lasted till 1765, when it was replaced by a fur one of a somewhat similar shape. The words of



Earthenware Hand Grenade, 1651, closed by hardwood plug having channel for fuse.

command at this period were: "Sling your firelocks—handle your matches—open your fuse—guard your fuse—blow your matches—fire and throw your grenades—return your matches—handle your slings." Such detail one would hardly consider conducive to a rapid rate of fire. By the time the fur cap came into wear the grenadiers had to a very large extent given up the use of the hand grenade, but the grenadier companies were still composed of the biggest and finest men in the different regiments. Toward the end of the eighteenth century it became the custom to form grenadier and light infantry battalions provisionally from these companies of the different regiments employed together on an expedition or campaign. This proceeding, while certainly providing a few battalions of extremely high-class soldiers, must yet have had a bad effect on the force at large, every regiment losing its smartest and best men just when they were most required. In fact, the same evil effects must have been felt as (according to a German critic) were experienced by British infantry during the late Boer war on account of their picked men being drafted to the mounted infantry. "The infantry were then robbed more and more of their better elements; . . . and an increasing demand arose from all sides for mounted troops. So only the elements of least value remained behind with their battalions—men who were bad shots, with but little smartness about them." This must have been recognized before the end of the eighteenth century, for we do not find many instances of the practice in the early wars of the succeeding century.

The pointed fur cap gave place to a larger, round-topped one with a brass plate and glazed peak and adorned with cords and tassels. In 1835 the plainer and bigger fur head-dress, much like what is now worn, but rather higher, came into vogue and has continued with modifications to the present day. At this time, too, it is interesting to note, the Blues also wore the fur grenadier cap. Abroad, the big fur grenadier cap had an extensive vogue in almost all armies, but at the present day the only foreign regiments wearing it are the Belgian grenadiers and gendarmerie, the Russian palace guard, the Danish guards, the Mecklenburg-Schwerin grenadier regiment, the Dutch horse artillery, and a New York veteran association known as "The Old Guard." It may be remarked, however, that the high eighteenth-century miter cap, but with a metal point, is still worn by the First Prussian foot guards, the First Prussian guard grenadier regiment, and the famous Russian Paul regiment of the imperial guard.

As for the grenade itself, the fighting in the Far East has shown it to be, with modern high explosives, a most formidable and destructive weapon, and it is possible that we may yet see a revival of the grenadier companies that gained such renown by their prowess in bygone times.

THE PROPAGATION OF BUTTERFLIES AND MOTHS UNDER ARTIFICIAL TEMPERATURE CONDITIONS.

By PROF. M. STANDFUSS.

THE old doctrine of the permanence of natural species is dead and buried. It did not long survive the blow which it received from the great work of Darwin. The present generation of biologists is convinced that the almost infinite variety of forms, species and genera is the result of a slow and continuous process of development which goes on now as it did at all past epochs. To-day all naturalists agree that the relationship of species is not a mere figure of speech, but a true kinship of blood.

But the adoption of this idea of development—the theory of evolution—gave biology its greatest problem, the determination of the causes of variation and the laws of the transmission of individual variations and their fixation in the course of generations.

The occurrence of individual variations and their tendency to reappear in offspring being granted, the theory of "natural selection through the struggle for existence" gives us a conception of the evolution of the organic world which is peculiarly satisfactory because it presupposes no mysterious forces foreign to our daily experience. It was this fact, in conjunction with Darwin's masterly presentation, supported by his unparalleled knowledge of detail, that brought about the adoption of the doctrine of evolution.

But the question remained: Whence come the variations? And another question was soon added: What peculiarities must a variation possess in order to be transmissible to offspring? For everyday experience teaches that not every variation is transmitted under all circumstances.

Weismann, the celebrated zoologist of Freiburg, appears to have grasped this problem most effectively. His experimental investigations have convinced him that peculiarities or variations acquired during the life of the individual through the influence of its environment are not transmissible to posterity.

This would dispose of the theory that the influence of the ever varying environment is the cause of transmissible variations and thus furnishes the raw material of the process of natural selection. A possible inference is that the source of variation lies in the substance of the germ cell and that the variations are determined by the various possibilities in the development of the embryo, through a sort of internal selection. Evidently, however, this is no solution of the problem but rather a denial of the possibility of solving it.

Oskar Herting dismisses Weismann's doctrine of a "continuous germ plasma" as a mere resurrection of the old "box within box" theory of pre-formation, or the pre-existence in the ancestor of an infinite series of descendants. The "epigenetic" theory of heredity of Herting, who denies the continuity of the germ (which he regards as differing from other cells only functionally and as possessing no specific germ plasma differing structurally from ordinary protoplasm) becomes tenable if we reject Weismann's premise and admit the transmissibility of acquired peculiarities. (The two theories are not really so irreconcilable as the impotence of language to cope with the problems of modern biology may make them appear.)

If acquired characters can be transmitted to offspring it becomes possible to understand the formation of varieties by the effect of environment and natural selection, and a broad field or observation, closed by Weismann's theory, is opened.

Hence it appeared well worth while to make experiments in heredity which might throw some light on this question, especially as carefully observed series of facts are always valuable in view of the difficulty and complexity of the subject of heredity. In this research I endeavored both to obtain direct evidence of the inheritance of acquired characters and to discover the causes of the negative results obtained by previous investigators.

I. THE LAW OF INHERITANCE.

I first studied the progeny of crosses between geologically recent types (without regard to their origin) and older types, both being spontaneous or furnished by untrammeled nature. The experiments fall into three groups, according as the two crossed forms belong to the same species, different species of the same genus, or different genera. I cannot here discuss the methods by which the relative biological ages of two forms can be determined with a high degree of probability. In general it may be observed that all the butterflies and moths are comparatively recent, as is proved by their vital dependence upon flowering plants which are certainly not geologically ancient. Consequently the series of species is almost complete, a fact which facilitates the determination of the relative ages of different species. The experiments, which continued 28 years, from 1873 to 1901, involved 30 species and 54,200 individuals.

First Group. Crosses Between Varieties of the Same Species.—The common German linden moth (*Dilina tiliae*) has a variety in which the dark central band of the anterior wings is more or less completely obliterated. This variety was crossed with the normal type in every possible way, with the following results:

1. Male, normal. Female, aberrant. Brood, 72, all normal.

2. Male, normal. Female, aberrant. Brood, 65, all normal.

3. Male, aberrant. Female, normal. Brood, 68 normal and 1 slightly aberrant female.

4. Male, aberrant. Female, normal. Brood, 51 normal and 1 female closely resembling the male aberrant type.

5. Male, aberrant. Female, aberrant. Brood, 77 normal, 1 male and 1 female approximating to the aberrant type, 1 male and 1 female intermediate between normal and aberrant type.

The aberrant variety used in these experiments is quite rare and the experiments were made possible only by the collection of more than a thousand pupæ from all parts of central Europe. The percentage of recurrence to the normal form is evidently very high. The proportion of aberrant forms in the offspring is small to preserve the aberrant type, a result which is confirmed by observation of the species in the state of nature.

Crosses of normal with aberrant forms of *Argynnis lathonia*, *Gastropacha tremulifolia*, *Agrotis linogrisea*, and other species, also produced few or no aberrant offspring.

The usual result was that the apparently spontaneous natural variety or aberrant type was represented by a very few individuals of the brood, while a few others were of types intermediate between the normal and aberrant types of the parents. In some cases, however, the broods were composed, in definite proportions, of normal insects and insects of the aberrant variety, without a single intermediate form. In one case, where a male "nun" (*Lymantria monacha*) was crossed with a female of the perfectly black variety (*L. m. eremita*) the brood contained, in addition to perfect representatives of each parent, a number of individuals in which the colors of both parents were present, not blended, but in sharply contrasted patches of irregular form and arrangement. Similar results were obtained with *Agliatan*, *Amphidasys betularia*, and *Spilosoma lubricipeda*, each crossed with a natural aberrant variety.

In such cases we are wont to speak of "antagonistic characteristics" which, it is assumed, cannot be blended harmoniously in a single individual. Bateson has been occupied for years in the study of these phenomena. In crosses between two local varieties of the same species (*Callimorpha dominula* of Switzerland with its Italian variety *persona*, *Spilosoma rustica* of Calabria and Roumania with its variety *mendica* of France, Germany, and northern Switzerland) almost all of the offspring were nearly or quite indistinguishable from the geologically older form (the first mentioned in each case).

Second Group. Crosses Between Different Species of the Same Genus.—A long series of experiments was devoted to crossing species and to crossing the hybrids thus obtained with each other, both parent species, and other species of the same genus. Broods resulting from thirty-two primary, secondary and tertiary crosses were raised to maturity.

Here also the markings as well as the biological character of the older parent species appeared in the most striking manner in the hybrids.

Some of the hybrids even exhibited genuinely atavistic characteristics, both morphological and biological. This atavism was especially well marked in the hybrid *Saturnia emiliae*, derived from the male of the small, and the female of the great peacock moth. In many instances the brood closely resembled a third natural species of intermediate size. Now there are good reasons for believing that this species is older than the small moth and that the latter is older than the great moth. In this case, therefore, the hybrid went back beyond the present type of the male parent

to the type from which it may have been derived.

Third Group. Crosses Between Species Belonging to Different Genera.—After much labor, many total or partial failures and the sacrifice of a great quantity of living material I succeeded in bringing to maturity the offspring of a number of crosses between males of the delicate linden moth (*Dilina tiliae*) and females of the very dissimilar, robust peacock hawk-moth (*Smerinthus ocellata*). In this case, also, nearly all of the hybrids very strikingly resembled the older parent species, *Dilina tiliae*.

This result is very instructive because the male *Smerinthus ocellata* crossed with the female of an allied species, the poplar moth *S. populi*, also produces hybrids in which the conspicuous and highly differentiated markings of the spotted moth (*S. ocellata*) are almost or entirely absent. It appears, then, that this comparatively recent and highly developed species (*S. ocellata*) is unable, either as a male or a female parent, to impress its characteristics strongly upon the offspring produced by crossing it with older species.

This prepotency of the older type, so commonly observed in hybridizing, appears to me to be the key to the difficulty of obtaining evidence of the transmission of inherited characters to offspring. The newly acquired and feebly established character is almost certainly overwhelmed by the older one, which has become firmly fixed in the course of a long series of generations, unless the new character is supported by some external influence.

This thought opens a new view of possibilities. If the environment can exert the slightest effect on the germ cells, as it does on the *soma* or rest of the body, the summation of such invisible effects continued through many generations may ultimately result in perceptible variation, in defiance of the power of the earlier fixed type.

The natural conditions which may produce such a transformation, through the influence of the environment, cannot be exactly imitated by experiment. The brief duration of human life, even the life of the human race, in comparison with the periods of time here contemplated, confines our observations within so narrow limits that it requires almost childish simplicity to believe that we shall ever be able to observe the progress of evolution directly. (The life of the dragon's blood tree of Orotava—the individual, not the species, genus, or order—is estimated at several thousand years.) Therefore we shall always be restricted to inferences from indirect evidence and experimentally we can only hope to produce, by exerting very strong influences upon forms peculiarly susceptible to variation, something remotely resembling the transformations which we are supposing nature to effect in the course of immeasurably long periods. This limitation illustrates both the strength and the weakness of experimental work in this field.

The results of my experiments are given below:

II. ARTIFICIAL VARIATIONS.

Several conditions in the life of insects may conceivably cause variation. Soon after 1870 I began to investigate these conditions with a view to making them the basis of experiment.

Spilosoma lubricipeda has a variety (*zatima*) distinguished by the great size of its black spots, and various species of *Callimorpha* have varieties with yellow wings. All of these aberrant varieties are found only on and near the coast. I fed larvæ of the normal species with leaves soaked in salt water. After pupation a number of the spilogomas showed black spots larger than the normal type. A similar change occurred in *Simenthastri*. The effect upon *Callimorpha dominula* was slight but unquestionable, consisting in an approximation toward the Italian local variety. The dark markings were increased in size and the carmine tint of the posterior wings brightened and approached vermilion.

I concluded that I had discovered a determinant of color and pattern in the character of the food but I was soon compelled to abandon this conclusion, for in subsequent and greatly varied experiments on the effect of diet I obtained no change in markings worth mentioning but only alteration and degradation in size and color.

In 1879, following the example of Hofmeister and Weismann, I began experiments on the effect of temperature. In contrast to these investigators, however, I have experimented with pupæ of many species within an extended range of temperature. I have also raised a number of species from the egg to the perfect insect under the constant influence of high temperature. Altogether I have employed 47,700 individuals belonging to more than 60 species. The results of some of the experiments with pupæ follow: (*a*) Many species naturally produce two broods annually and in some of these species the brood in which pupation occurs in the warm season differs greatly in appearance from the insects which have undergone this transformation in the cold season. This phenomenon is known as seasonal dimorphism, and the two forms are called seasonal varieties. In the state of nature these varieties are very constant and do not blend into each other. I succeeded in evolving moths with the external characteristics of the summer varieties of some of these species from the pupæ of the cold season, and conversely, by varying the temperature. The transformation was most successful with *Araschnia levana* and its summer variety *prorsa*, *Polygonia c-album* and its summer variety *hutchinsoni*, and *Chrysophanus amphidamas* and its summer variety *obscura*.

(*b*) Many species of animals and plants differ in appearance according to their habitat, or exhibit local varieties. In some cases these local varieties can be produced by experiment, perfectly or approximately. For example, the *Vanessa urticae* of Zurich (popularly called "the little fox") can be almost converted into the Arctic variety (*polaris*) and also into the Corsican and Sardinian variety (*ichnusa*). The summer form of our Swiss "swallow tail" can be changed to the summer form of the variety found in Syria and Palestine. *Doritis apollinus*, from Anatolia, can be made to assume the more gorgeous garb of its Syrian variety, and *Thais rumina* from Portugal the gayer dress of its southern variety *canteneri*, which is found in Malaga but not in Portugal. Similar results were obtained with pupæ of *Thais polyxena* from Vienna and *T. cerisyi* from Amasia, from both of which southern local varieties were experimentally produced. *Callimorpha dominula*, a pretty little moth of the "bear" family (with furred larva) which is common in Switzerland, can be transformed perfectly into its Asiatic variety *bithynica*.

It must not be supposed that the "swallow tail," for example, which emerges at Zurich in July at an average temperature of 65 deg. F. can be converted into the Palestine summer variety by keeping the pupa at 76 deg. F., the mean* July temperature of Jerusalem. Far from it! This result can be obtained only by the continuous action of a temperature of 99 deg. or 100 deg. F. The temperature of Jerusalem could produce the Jerusalem type only by repetition of its influence through countless generations.

For analogous reasons pupæ of *Doritis apollinus* from Syria do not develop the slightest approximation to any northern variety even when exposed to the open air in March at Zurich. Every local variety that was investigated proved to be very stable, so that prolonged exposure to a temperature widely different from its accustomed temperature was required to effect an appreciable change.

(*c*) Rare and strikingly aberrant forms of certain lepidoptera, notably the "admiral," and other species of *Vanessa*, were discovered as long ago as 1780. These aberrations, also, can be produced artificially by the influence of temperatures to which the species in question are occasionally, but not usually, exposed in the free state. Thus the natural occurrence of these puzzling and much discussed forms is explained.

(*d*) The males of many butterflies, like those of many birds, differ greatly in color from the females. In a few cases it was found possible to destroy this sexual dimorphism artificially. The male of the little "lemon" butterfly of early spring is bright yellow, while the female is nearly white. By the action of heat the female was caused to assume more or less perfectly the color of the male. The beautiful Alpine butterfly called the "Apollo" (*Parnassius Apollo*) is also differently colored in the two sexes. The colors of the male were developed in the female by heat, and those of the female were given to the male by cold.

(*e*) In the experiment last mentioned there was a manifest approximation to a distinct and very different *species*, the Siberian *Parnassius discobolus*. In the same manner the peculiar "swallow tail" butterfly of the mountains of Corsica and Sardinia (*Papilio hospiton*) was approximated to our common Swiss "swallow tail" by heat, and *Chrysophanus dispar* to *C. hippothoe* by cold.

Various species were also subjected to the influence of high temperatures, from 68 deg. F. to 86 deg. F., throughout life, from the egg to the imago. The effect varied with the species. In a majority of species the larval period of growth was considerably shortened by the increased temperature and the perfect insects were much smaller than normal specimens, besides exhibiting other differences. A minority of species retained the normal period of growth and became greatly increased in size as well as otherwise altered. These results are very noteworthy because there are many pairs of natural species related to each other biologically in the same manner as the forms thus artificially produced are related to their normal types. For example, the great poplar moth (*Gastropacha populifolia*) makes its natural larval growth in about 25 weeks of cool weather, in autumn and spring, while a nearly related species (*Epicnaptera tremulifolia*) completes its growth in 14 weeks in summer, but attains a much smaller size. When the brood of the large moth is subjected to the temperature normal to the small one, the moths produced by the experiment exhibit many of the characteristics of the small species. This experiment throws light on the probable cause of the separation of the small from the large species, which for various reasons must be regarded as the older.

III. INHERITANCE OF ARTIFICIAL VARIATIONS.

In 1897 I succeeded in obtaining an answer to the question of cardinal importance: Can the variations arising in these experiments be transmitted to offspring? Thirty-two males and 10 females of *Vanessa urticæ*, all strongly aberrant, yielded a progeny of which the following record was made:

Two of the 10 females produced no young.

A small percentage of the brood produced (probably) by 7 pairs was raised to maturity and the butterflies thus obtained were entirely normal.

An eighth pair produced 43 butterflies, of which 1 deviated widely and 3 deviated slightly from the normal type in the direction of the aberrant form of their parents. All of these 4 aberrant young were males.

The most aberrant female alone—the 32 males did not differ appreciably in degree of abnormality—transmitted newly acquired characteristics to a few of her offspring. Hence the power of transmission appears to be dependent on the degree of abnormality.

As the broods were very incomplete owing to disease, a repetition of the experiments on a large scale is highly desirable. Nevertheless, the data obtained in regard to the effect of environment in causing variation in living organisms are very significant, in view of the fact that such abnormal individuals as were here found among the progeny of abnormal parents are never found among many thousands of insects of normal pedigree, developed under the same conditions.

The main point is this: *a portion, though a small one, of the offspring unquestionably exhibited variations which had been produced artificially in the parents.*

The entire research may be summed up as follows: The first object was to ascertain by experiment what sorts of variations, in respect to their nature and origin, can be transmitted to offspring and, hence, possibly preserved. One method of experiment consists in crossing and hybridizing older and newer forms of the same and of different species and noting which form shows the greater chance of survival by impressing its characteristics the more strongly upon the progeny. The invariable result of the experiments was that the geologically or phylogenetically older type prevailed over the younger. In almost every case there is abundant morphological and biological evidence of the relative ages of the two types, but this point must be established carefully and with certainty as the entire argument obviously rests upon it. In my Manual of Palearctic Butterflies (1896) I have attempted to determine the relative ages of the three "peacock moths" (*Saturnia spini, S. pavonia, S. pyri*) and no exception has been taken, to my knowledge, either to my reasoning or to my conclusions.

My experiments in hybridization appear to prove that some external influence must intervene to overcome the resistance offered to the new variation by the long-established type. But not every conceivable external influence is effective. Just as a resonator responds only to the tone to which it is tuned, so must the external influence correspond to a possible direction of development. Hence the success of experiments made to detect this reaction of the organism to its environment will depend on the selection of influences to which the organism can respond. The chief of these influences are those which actually have exerted appreciable effects during the past history of the earth and the most effective of all are climatic influences. From the complex which we call climate the factor of temperature is most easily isolated and exaggerated to such a degree that we can hope to compensate the shortness of duration of the experiment, at least partially, by the increased intensity of the momentary effect.

The temperature experiments have given positive results, in every respect, for it must be remembered that the variations involved not only changes in color and pattern but also, in many cases, changes in the shape of scales and the form and size of wings, and other distinctly morphological alterations.

Again, the transmissibility of modifications thus produced by the influence of heat and cold, was positively proven in several cases. Obviously, however, only those variations can be transmitted to the offspring of which the latter is capable or which it may be said to possess potentially. This statement remains true whether we, with Weismann, refer the variation to the germ plasma alone or, as I prefer to do, attribute it to the organism as a whole.

All experiments with agencies that correspond to no variation of which the organism is capable, and especially all mutilation experiments, must be fruitless. When Weismann cut off the tails of many successive generations of mice (without producing any naturally tailless animals) he surely made a very unfortunate choice of an experiment designed to prove or disprove the transmission of acquired characteristics.

There is no cogent reason, indeed, for regarding the reproductive glands as separate and distinct from the rest of the body. The true state of affairs may be conceived as follows:

Every cell of every individual of the same species represents that species. Every human cell, for example, is "man." This law is easily demonstrable in many plants, including some of higher orders. A new plant may be produced from almost any fragment of a begonia leaf. The law, however, is obscured by the differentiation of the cells in the organism and the relations of organisms to each other. The more highly specialized the cell, and the organism as a whole, the less of this general character of the species is left in the cell. The special function of the cell may so completely engross all its powers that at last even the fundamental property of cell division is lost—as in nerve cells, at least of higher animals. A cell becomes a germ cell in the narrowest sense of the term not through the mysterious possession of "germ plasma" but because it has no special function in the life of the organism and consequently preserves all of its original activities unimpaired. In a modified sense all cells that are capable of self-reproduction may be called germ cells. In this respect there is an unbroken chain of types of cells, as there is of types of organisms. The fate of a cell in becoming a germ cell, or a muscular, nervous, glandular, or other cell, is decided by the place in the organism to which it is assigned in the development of the embryo. If this place is that of the incipient reproductive gland the cell necessarily becomes a germ cell. In its relation to the external world the organism is to be regarded as a unit, not as a congeries of cells—a view to which no rational

* Merrifield has proven that a periodically varying temperature has the same effect as its mean.

objection can be made. Light and darkness, color, heat and cold attack and affect the entire organism, producing visible alterations of form and color in the external parts and corresponding potential changes in every cell of the organism. Every element tends to develop in harmony with the now modified organism according to the capacity for development which its specialization of function has yet left in its possession. This law of development includes the germ cells which we assume to be without special function. To describe all the obstacles that prevent the realization of these tendencies would be to expound the entire theory of heredity.

My conclusion is this:

The mutual influence exerted between the organism and its environment produces individual unstable variations which are more or less perfectly transmitted to offspring, and eliminated or fixed in definite form by selection.

THE DECKER PRIMARY BATTERY.*

By PROF. FRANCIS B. CROCKER.

ON May 16, 1888, the writer read before the American Institute of Electrical Engineers a paper on "The Possibilities and Limitations of Chemical Generators of Electricity." This paper discussed and compared the various types of primary cells. It was shown that about one pound of zinc and a few pounds of other materials were capable of producing one horse-power hour, and the statement was made that "the possibilities are very, very great." On the other hand, little or no progress had been made with the primary battery for almost half a century, so that the outlook was very discouraging, especially in regard to its structure and handling. Hence, the conclusion was reached that "the *apparatus* is at fault, not the *chemical action*." (*Italics* in the original). Let us consider briefly the principal historical facts.

The original form of primary battery or *couronne de tasses*, which was the first known source of electric *current* in contradistinction to static *charge*, was invented by Volta in 1800. Amalgamation of the zinc was introduced by Sturgeon in 1830. The two-fluid type of primary cell with porous cup to separate the fluids was invented by Daniell in 1836. The use of nitric acid as an electro-negative fluid or "depolarizer," more powerful than the copper sulphate of the Daniell battery, was due to Grove and dates from the same year (1836). In the Grove cell a platinum negative plate is employed to withstand the action of the nitric acid, and Bunsen in 1842 substituted carbon for this expensive metal. Poggendorf in 1842 devised a single-fluid cell in which a solution of potassium bichromate mixed with sulphuric acid was used as a depolarizer instead of the nitric acid of Grove, thereby avoiding the obnoxious fumes without material sacrifice of power. One is at a loss to point out any radical or even important advance in primary batteries since the time of these fundamental improvements. In other words, so far as the types now on the market are concerned, they are not substantially better than what might have been obtained more than sixty years ago. This is all the more remarkable when it is remembered that practically all the modern applications of electricity with the exception of the telegraph have been made since 1876, a period only one-half as long during which the dynamo-electric generator has been developed from one horse-power to ten thousand, its efficiency and mechanical construction being vastly improved at the same time. It should be noted that the Leclanché cell (with sal-ammoniac solution) was brought out in 1868, and the so-called "dry" batteries about twenty years ago; but these types are applicable only to intermittent service, such as ringing electric bells, and even for short periods are incapable of giving any considerable electric power. Hence, they constitute a special class adapted to perform merely light duties, and should not be included or compared with batteries capable of operating electric lights and motors. The Lalande battery was invented in 1881, and is now manufactured and used to supply considerable amounts of electric power; in fact, it is practically the only type of primary cell now employed to any extent for this purpose. Definite statements and figures in regard to this battery will be given later.

The quotation from the writer's paper in 1888 to the effect that "the *apparatus* is at fault, not the *chemical action*," applies equally well to the primary battery of 1906 so far as any types now upon the market are concerned. They consist usually of separate glass or porcelain jars, clumsy and liable to breakage; electrical connections are made by wires and binding posts, inconvenient and exposed to corrosion as well as to mechanical injury, with no way to supply fresh liquids except by the laborious and sloppy process of pouring them into each cell separately. A picture of a primary battery of 1850 compared with one of 1906 would show little difference in favor of the latter, certainly nothing radical. On the other hand, compare a dynamo of 1878 with one of 1906, an interval exactly half as long! This Chinese progress of the primary battery, which was discouraging in 1888, became more so as time went on; and the opinion of the writer, if expressed in 1904, would not have been much more favorable than in 1888, since there was little or nothing upon which to base hope of material advance in this direction. The principal weak points of the primary battery are, first, high internal resistance, limiting its power and efficiency; second, weakness and looseness of its parts, exposing them to breakage or derangement; third, exposure of the electrical connections to corrosion as well as to mechanical injury; fourth, the great inconvenience and the likelihood of spilling the liquids when a battery is being emptied of an old charge or supplied with a new one; fifth, the high cost of the materials as well as labor required for recharging. Practically none of these five difficulties has been overcome or even mitigated so far as published information goes. Recently, however, it has been the writer's good fortune to examine and test a primary battery in which the first four of these defects are actually overcome, and there is good prospect that the fifth will be largely reduced.

FIG. 2.—CONTAINING VESSEL COMPRISING FOUR CELLS.

CONSTRUCTION AND OPERATION.

The battery to which I refer has been developed during the last two or three years by Mr. F. A. Decker, of Philadelphia. It is of the two-fluid type, with zinc plates immersed in dilute sulphuric acid, and graphite plates in a solution of sodium bichromate and sulphuric acid. The materials and chemical action are, therefore, similar to those of other batteries, the original features being found in the *construction* of the parts and the manner in which they are put together. The size and number of plates employed in each cell depend upon the current required, but ordinarily there are two or three flat zinc plates about 5½ inches wide by 9½ inches high, each weighing about one pound. Each zinc plate and the dilute sulphuric acid surrounding it are contained in a flat porous cup. In order to form such a cup, two unglazed earthenware plates with thickened edges and diagonal strengthening ribs are shaped separately in steel molds, a special clay mixture being employed to obtain any desired porosity. These plates are made extra thick to prevent warping in burning, and produce true flat surfaces and straight edges. They are then united to form a flat cup, after which it is ground down on each surface to the desired thinness. In point of fact the finished walls are very thin, so that light will show through them, which enables the degree of uniformity and thinness to be readily determined. The grinding operation involves little time or skill, being performed by half-grown boys. In this way a flat porous cup is obtained, perfectly true on all sides and with walls much thinner than could possibly be made if it were attempted to form a complete cup in the first place. At the same time this cup is amply strong, no breakage being found to occur even in automobile service. Two of these porous cups *P P* are shown in Fig. 1 in combination with three graphite plates *G G G*, and at P_1 with a zinc plate *Z*; also one of these porous cups sawed through vertically is seen at P_2, the strengthening ribs on the interior surface as well as the thickened edges being visible. The exceeding thinness of the walls of these cups tends to reduce the internal resistance to a minimum for any two-fluid cell, and the fact that these walls are true, permitting the graphite and zinc plates to be placed close together, also tends to minimize the resistance. By actual test, it is only 0.013 ohm for a cell of the kind described with two zinc and three graphite plates, all connections and the resistance of the plates themselves being included.

The negative plates are of graphite, being corrugated so as to offer large surface for the free action of the depolarizer; and also provided with thickened edges and diagonal ribs to give them strength as well as to decrease their electrical resistance. Three of these plates are represented at *G G G* in Fig. 1, as already stated, and half of another is seen at G_1, having been sawed in two to show the corrugation.

The space around the porous cups and graphite plates is filled with the depolarizer, consisting of a solution of sodium bichromate mixed with sulphuric acid, which is introduced into the containing vessel of hard rubber as explained later. One of these vessels comprising four cells is shown in Fig. 2. In order to assemble a battery, the two porous cups *P P* in Fig. 1, each containing a zinc plate, with the three graphite plates *G G G*, are placed in one of the cells of the containing vessel in Fig. 2, other similar sets being put in the other cells. To supply dilute sulphuric acid to the porous cups, each one communicates through a small opening at the bottom with a conduit in the base of the containing vessel. The two outlets of this conduit in each cell are shown in the bottom of the containing vessel in Fig. 2. The openings of the two porous cups are respectively connected to these outlets by means of vulcanized joints free from leakage or acid action. The conduits leading to the various cells are branches from the main conduit that extends the entire length of the containing vessel under one side. The depolarizing fluid is supplied by a similar set of conduits, but in this case it is sufficient to have one simple outlet in each cell. It is objectionable to have direct electrical connection between the various cells through the liquid contained in these conduits, because a certain short-circuiting or leakage of current would occur. This is reduced to an insignificant amount in the Decker battery by making the branch conduits of considerable length and small cross-section. A containing vessel of four cells with the upper part cut off is shown in Fig. 3. The two outlets in each cell which supply the two porous cups with dilute acid are connected to the main conduit *C* by a branch conduit extending across the cell. Similarly, the outlet that feeds each cell with depolarizer is connected by a branch conduit to the main conduit C_1, on the other side. In this way the total length of the liquid connection between the cells is made very considerable. The main and branch conduits, with their connections to each other and to the cells and porous cups, are composed of hard rubber all vulcanized together, forming what has been aptly called an irrigation or drainage system, since it performs both functions. The several cells that make up the containing vessel in Fig. 2 are also vulcanized together, so that the complete battery with all its cells, conduits, and porous cups constitutes one substantially integral mass, with no loose joints or parts. The graphite and zinc plates as well as their connections are also held very firmly in place, so that the battery as a whole may properly be claimed to be an integral structure or unit.

The electrical connections in batteries have always been a source of much trouble, being difficult to make and still more difficult to maintain because of the corrosive action of the liquids. In the Decker battery the connection to each graphite plate is made by a brass screw extending several inches into its thickened upper edge. One of the screws is shown at *S* in Fig. 1, and the end of another is seen projecting from a carbon plate at *s*. When the plate is in place, this end of the screw passes out through a hole near the top of the containing vessel, being held firmly by a nut on the outside. The connection to the zinc plate is made by means of a long tapering zinc plug inserted in a zinc block *B* and B_1 in Fig. 1, enabling the plate

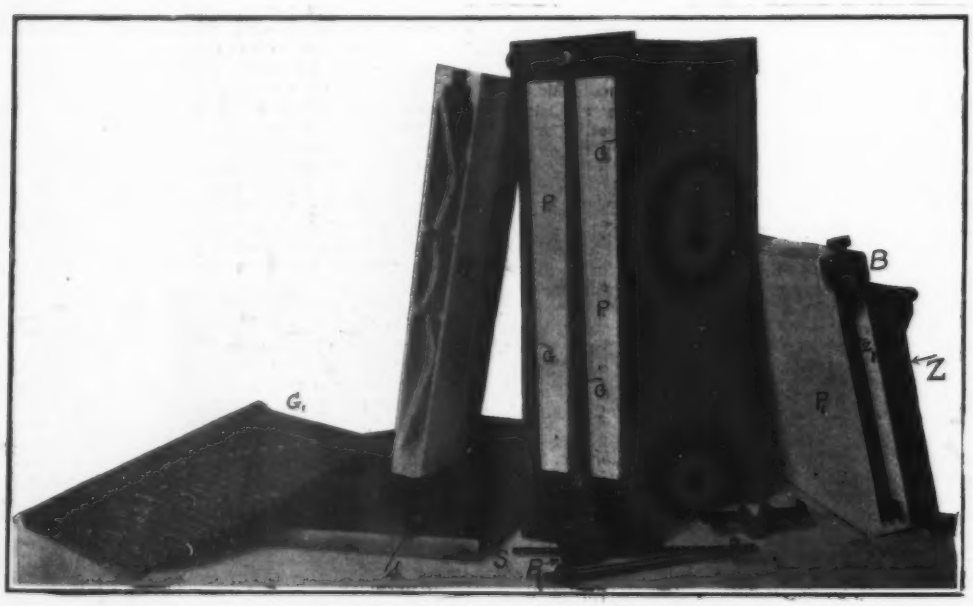


FIG. 1.—PARTS OF DECKER PRIMARY BATTERY.

* A paper read before the American Electrochemical Society, October 9, 1906.

to be readily renewed, at the same time making a good mechanical as well as electrical joint. This zinc block is held in place by a screw passing through the wall of the containing vessel with its head outside. The carbons of one cell are connected together and to the zincs of the next cell by a brass strip placed under the nuts and heads of the screws. We see, therefore, that connection is made to the graphite plate (impregnated with paraffin along its upper edge to make it impervious) by a long screw imbedded in it, and giving extended contact surface. The zinc plate, plug, and block being all of the same material are free from voltaic action, and all the rest of the connections, including those between the plates of each cell as well as between the cells, are *external* to the containing vessel. Hence, all trouble is avoided from corrosion, loose connections, or poor contacts of any kind; this statement being borne out by experience. It is this care as to correctness of design and perfection of details that frees this type from the serious defects in structure and operation that have characterized primary batteries for 106 years.

The two fluids are caused to run into or out of the battery by connecting the two main conduits $C C_1$ (Fig. 3) already described with two supply tanks by means of rubber or lead pipes, each main conduit being provided with a socket or nipple to which the pipe is attached. The fluids may be caused to flow by a pump or siphon or by raising and lowering the supply tanks. A neat method is to force air into the supply tanks, thereby driving the liquids into the battery, allowing them to run back by gravity. This is the arrangement represented in Fig. 4, a battery of sixteen cells being supplied from two tanks below. The switch above on the right not only closes the circuit and light lamps, for example, but also turns air pressure into the tanks, thus filling the battery. The large cell on the floor to the right is a type having ten zinc and eleven graphite plates, being capable of giving 120 amperes for six hours at an average of 1.7 volts. It is intended for heavy work, having a lead-lined containing vessel of wood.

RESULTS.

The results obtainable from the Decker battery are shown by tests made personally by the writer. A cell of the form described, having two zinc and three graphite plates, was discharged for a period of 5¼ hours at 24 amperes, the external potential falling from 1.9 to 1.3 volts. In other words, the cell gave 126 ampere-hours at an average voltage of 1.73, or 218 watt-hours. The cell was then shaken so as to stir the liquid, and gave 24 amperes for 53 minutes longer. This corresponds to the condition that would exist in electric vehicles, boats, and train lighting. The total output, therefore, was 147 ampere-hours at 1.684 average voltage, or 247.55 watt-hours. As the complete cell weighed 16 pounds 14 ounces, including all solutions, connections, etc., the output was 14.7 watt-hours per pound of total weight, which is an output about twice as great as that obtained from the standard types of storage battery now manufactured and used. To put these figures in simple form for ordinary business purposes, it may be stated that a cell weighing 17 pounds gives 150 ampere-hours at an average of about 1.7 volts, or about 250 watt-hours, which is equivalent to one-third of a horse-power hour. The output is nearly 15 watt-hours per pound of complete cell.

In this connection it should be remembered, however, that the liquid constitutes only about one-half the total weight of the battery, hence it would be possible to carry in tanks an additional amount of solution equal to the weight of the battery, in which case we could obtain three times as much electrical energy with only twice the total weight. In other words, the output would be 22.5 watt-hours per pound, which is about three times that obtainable from a standard storage battery. It would not be necessary to renew the zincs, because they are sufficiently thick to be equivalent to three or more charges of liquid.

A second advantage of the Decker battery compared with the storage battery, in addition to this large saving in weight, is the facility of recharging it by simply running out the liquids and refilling with fresh solutions, which can be done in five or ten minutes compared with five hours or more required for recharging a storage battery.

A third advantage of the primary battery is the fact that it has no limit in voltage beyond which the discharge cannot safely be carried. If desired, it can be discharged indefinitely until there is practically no power left. In the case of the storage battery, on the other hand, it is very objectionable to discharge below 1.6 volts per cell on account of the danger of "sulphating" and serious injury to the plates.

A fourth advantage of the primary type is the fact that it is not necessary to recharge it immediately after the discharge, whereas it is decidedly objectionable to leave a storage battery in a discharged state for any length of time.

The principal, if not the only, disadvantage to be considered, in comparing the Decker battery with the storage battery, is the rather high cost of recharging the former.

COST OF OPERATION.

The weight of zinc, sulphuric acid, and sodium bichromate required to give one horse-power-hour in the Decker battery, assuming all materials to be thrown away after being used once, would cost about thirty-five cents, which is a high rate. It should be remembered, however, that the several important advantages which have been pointed out will offset this item for many purposes and in many places. It would be absurd, of course, to claim that any primary battery can compete directly with the dynamo driven by steam, gas, or water power, where such a source is available. There are applications, however, for which it is not practicable or convenient, and these will be set forth later. Furthermore, the first cost of the battery is not high and its depreciation is very small. It is expected, also, that the cost of the materials required for recharging will be much reduced by recovering or regenerating them. That is to say, the liquids drawn off from the battery after it is discharged are treated electrolytically in suitable cells to regain the zinc and reoxidize the chrome solution. In this way there would be very little actual loss of materials and the cost of operation per horse-power-hour would be simply the cost of the electrical energy required for regenerating the materials plus the labor

FIG. 3.—CONTAINING VESSEL WITH UPPER PORTION CUT AWAY.

involved. The latter would not be great because the liquids could be transported in the tanks in which they are sent out and can be caused to flow through pipes into or out of the electrolytic cells. In this way the operation of recharging this primary battery would not cost much more than recharging a storage battery. The only real difference in principle between the two cases is the fact that the charging or regeneration and discharging of the former take place in different cells; whereas both operations are performed in the same storage cell. So far as transportation is concerned, the primary battery would have decided advantages: First, because tanks of liquid are much more easily portable than storage batteries, and second, the liquid for the primary battery weighs only one-quarter as much as an equivalent storage battery which must be carried as a whole, or, say, one-third as much, including weight of tanks. The recovery process has been experimented upon with encouraging results.

APPLICATIONS.

An electric vehicle cannot be connected with a dynamo except through a trolley wire or other fixed conductor. Where such connection is not feasible, as in the case of cabs, pleasure vehicles, trucks, delivery wagons, etc., the only electrical source of power now available is the storage battery. The advantages of the Decker compared with the storage battery have already been set forth and they are certainly very substantial. The higher cost of the electrical energy, which is the only disadvantage of the former, would probably be a small matter in many cases. The other items of expense in operating an electric vehicle or gasoline automobile are so high, for example, the cost of tires, that a little higher rate for electrical energy would often be insignificant or more than overcome by advantages gained. Furthermore, the depreciation of a storage battery is much greater than that of the Decker battery. A vehicle storage battery has a life of about 5,000 miles, after which the renewals would cost at least $120, or 2.4 cents per mile, which item is greater than the cost of the electrical energy at 10 cents per kilowatt-hour. Hence, several of these incidental items are higher than the cost of the energy itself. What has been said in regard to the electric vehicle would apply also to electric boats, the general conditions of service being similar.

For the purpose of lighting railway trains the advantages of the Decker battery already explained would all apply. In fact, it seems that this application is one of the most favorable of the various possible uses to which this battery may be put. The equipment could be much more easily applied to the cars than is possible with the electric generator and storage battery combinations now used, it being sufficient merely to carry the battery and tanks of liquid and not necessary to attach and connect electrical generators or other machinery. Furthermore, the power is obtained without any drain upon the power of the locomotive, which is sometimes taxed to its utmost with a heavy train and steep grades.

There are also many places in the country where it is either not possible or not convenient to obtain electrical energy by direct wires from a central station or electrical generating plant; in such cases, this primary battery would afford a simple and convenient source of supply. Electric lights for reading and for sick rooms, electric fans, advertising lights and devices, dental motors, and many other pieces of electrical apparatus may be operated in this way. The cost of electrical energy with regeneration of the materials would not be much if any greater than the rates charged by electric lighting companies in some of the smaller towns.

The Lalande type is the only primary battery now on the market from which any considerable current in amperes or power in watts can be obtained. One of these cells having approximately the same total watt-hour capacity as the Decker cell described weighs 25 pounds, compared with 17 pounds. It is not practicable, however, to discharge it at even one-eighth the rate in watts obtainable from the Decker cell, the latter weighing only about two-thirds as much. It is also a fact that the voltage of the Lalande type when giving considerable current is very low, falling to 0.3 or 0.4 volt with currents of 10 to 12 amperes, whereas the Decker cell, weighing only 17 instead of 25 pounds, gives 24 amperes at 1.9 volts initial and 1.7 volts average.

One might think that at 35 cents per horse-power-hour the cost of energy already given for the Decker cell without regeneration would be prohibitive; nevertheless, the cost of about $5.30 for the same amount of energy for cells of the Lalande type has not been found prohibitive, since batteries of this class have been and are being used in large numbers.

It is evident from the statement of facts contained in this paper that Mr. Decker has made a remarkable advance in the primary battery art.

Toulon is one of the cities on the Mediterranean coast which is using a large amount of current for electric lighting and power, furnished by a hydraulic plant at some distance off. This hydro-electric station is one of the largest of the plants which the company known as the Mediterranean Coast Company has put up recently. The company already has a number of hydraulic plants in the coast Alps, and this region is one of the most important in Europe in this respect. Soon the country will be covered by a network of electric lines which will connect all the leading coast localities from Marseilles to the Italian frontier. The electric plant which is now supplying Toulon is located at Entraygues, in the mountain region, and is distant about 36 miles from the city. A high tension is used on the overhead line, this reaching 28,000 volts. The Argens River, a rapid mountain stream, supplies a water head of 50 to 60 feet. In the dynamo house are erected three main generating groups, each composed of a double horizontal shaft Francis turbine of 1,000 horse-power coupled to an alternator of the three-phase type. These machines operate at 300 revolutions per minute. The three-phase current is sent into a bank of three transformers, where it is raised from 3,500 to 28,000 volts for the overhead line. On arriving at Toulon, the line is received in a sub-station, where a set of transformers lowers the tension again to 3,250 volts. From here the current is sent into two special stations, one for the lighting lines and a second for supplying direct current for the city tramways.

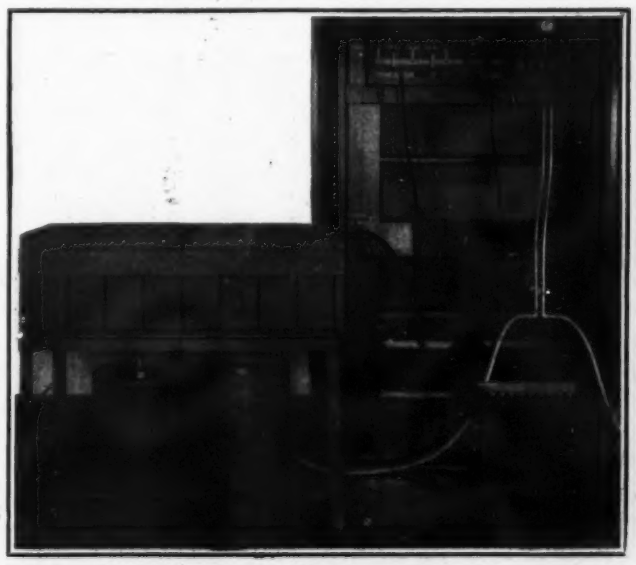


FIG. 4.—SIXTEEN-CELL BATTERY WITH SUPPLY TANKS AND CONTROLLING APPARATUS.

THE BAGDAD RAILWAY.

GREAT BRITAIN has regenerated Egypt, and Germany seems inclined to attempt the regeneration of the Asiatic dominions of the Sultan, and at the same time to make a substantial pecuniary profit by opening up the country by railways. This is to be effected without risk to the financiers involved, by securing from the Ottoman Government a guarantee of interest on the capital expended, and it is with this object in view that the Ottoman Government has recently been moved to demand an increase in the customs dues of the empire, a demand in which, so far, the great commercial powers have not seen their way to concur. An article by Mr. A. G. Bell, in the current issue of the Contemporary Review, shows how complete is the control now secured by Germany over the railways of the Ottoman Empire. In Europe Germans control wholly or partially 711 miles out of a total of 1,026, while in Asia they hold the Anatolia Railways, aggregating 636 miles, the 125 miles of the Bagdad line now constructed, and have a large share in the administration of the Smyrna-Afioum Karahissar line, 320 miles long, and also of the Mersina-Adana Railway, 40 miles long, while they are negotiating for the control of the Smyrna-Dineir line of 324 miles in length. As the Turkish Government lines have also been mainly engineered by Germans, only 638 miles out of the total Turkish mileage of 3,446 miles are quite independent of the Fatherland; while the same country holds concessions for the construction of 2,300 miles more, 1,300 miles of which form the portion of the Bagdad line yet to be completed. This latter railway, if constructed, will traverse the district which used to be by far the wealthiest and most densely populated of the globe, and under decent administration might yet recover no small portion of its ancient glories. For this, however, the construction of irrigation works seems more urgently needed than that of railways, which, in the present poverty-stricken state of the land will be totally unable to pay working expenses, and hence arises the anxiety to secure the increase in the customs dues, so as to have the means of making good from this source the anticipated annual deficit. The concession for the railway, nevertheless, bestows on the concessionaires a practical monopoly of the land, water-power, minerals, and timber along the route, which may prove highly profitable if the railway can be run at the expense of the imperial exchequer, instead of being compelled to pay its way. The difficulty in providing for this lies in the fact that in the absence of power to increase the customs dues there are no funds available for making good the expected deficits, and lacking these the astute German financiers are by no means particularly anxious to raise and risk the capital required.

ELECTRIC RAILWAY DEVELOPMENTS.

IN view of the recent great developments and extensions of the electric railway, a general review may be of interest. When, as to-day, the reports of the proposed electrification of steam roads become so common as to cause little wonder, well may the question be asked, "What will it all lead to?" Still another question insists on coming to the surface, viz.: "Is the A. C. motor likely to revolutionize electric traction?" Although the answers to these questions depend largely upon future developments and therefore cannot be exactly predicted, some conclusions can with certainty be drawn. The trend of developments is of special value in attempting to outline what may be expected in the future.

During the last ten years the electric railway business has developed far more rapidly than any other of comparable size. This is particularly true abroad, where over 90 per cent of the present roads have come into existence through displacement of horse or steam, or by new investment, during that period. In no other country than the United States has there been great development along the line of interurban railways, which require heavy equipment, operating at moderately high speeds.

The engineers of this country have so perfected and standardized the direct current equipment for this class of service, that there is little improvement to be expected in that line. The operating characteristics of suburban and interurban systems are not usually very dissimilar from those of ordinary city lines. Although the load is not distributed so evenly over these systems as in city railways, the concentration due to higher speed and heavier equipment is not so serious as to require any fundamental change in the character of the system. The economical limit of speed and weight of train units for this kind of system depends chiefly upon the one condition of distribution of the load. The gigantic undertaking of the New York Central Railroad to handle all trains within 35 miles of New York city by electricity is so far the greatest proposed development along this line. There has been much criticism and discussion as to whether some other system would not better fulfill the requirements of the case. It is not difficult to show that the choice made was the best one, because it rested on the fundamental consideration that no system of traction has yet been devised which can in any way compete with the standard D. C. system, on roads where the load has fairly even distribution.

Although a single New York Central passenger train will require upward of 2,500 kilowatts at times, this energy is such a small proportion of the total average load on a section fed from one power house, that the system can still be classed with those having a distributed load; the sole difference being that this one is on a scale of magnitude almost undreamed of a half dozen years ago. There were many problems to be solved in this undertaking, and the bold way in which the choice of the type of motor for the locomotive was worked out is an indication of the technical ability of the engineers employed. The new motors are unique in that the armatures are mounted on the car axles. The absence of gear losses makes their operating efficiency very high. Because of the simplicity of construction and consequent small depreciation made possible by their design, it is the best motor so far designed for use in high-speed D. C. locomotives.

These new electric locomotives are designed to haul a 450-ton train at a maximum speed of from 60 to 65 miles per hour. At present the New York Central's heaviest passenger trains entering New York city weigh about 875 tons, and more than one locomotive will be required to haul them at such speed.

It is seen upon analyzing the New York Central's proposed electrification, that the operating characteristics are not the ordinary ones of steam trunk lines where heavy fast trains are run at infrequent intervals. There has in fact been nothing of importance done or even attempted along this latter class of service, which will be called heavy concentrated loading.

The nearest approach to such service is found in some of the heavy interurban lines; the limit of speed and distance is soon reached in these lines using D. C., because of the great cost of delivering the current to the train. The third rail has extended this limit but slightly.

Five or six miles is the limiting distance of economical distribution at the standard voltage of 600. If a single station or sub-station can distribute to a distance of five miles in each direction, then stations must be built every ten miles along a line of railway. A concrete example will show how unsuited such an arrangement would be for heavy concentrated loading. Suppose a railway line 100 miles had only one train in operation. If this train required 1,000 kilowatts, then the power house capacity would be 1,000 kilowatts and each sub-station 1,000. There would have to be eight sub-stations or a total sub-station capacity of 8,000 kilowatts. The conducting system would also have to be sufficient at every part to deliver 1,000 kilowatts economically to the train. The investment in transforming or generating equipment must be all out of proportion to the power used in such service. The case assumed is an exaggerated one for the purpose of illustration. The principle involved is really the root of the difficulty which must be overcome before ordinary steam traffic can be replaced by electric.

In order to overcome the difficulties, either the characteristic of the traffic must change from large-train units at infrequent intervals, to distributed service, or the distance to which energy can be efficiently delivered to moving trains from one station must be increased. The former solution may in some cases play an important part, but the general solution of the problem rests with the latter method, in which the first necessary requirement is a high voltage of distribution to the train. If a much higher voltage than 600 is used, the third rail is entirely unsuited. It would be too dangerous to life and cannot be well enough insulated for good operating conditions. A higher distributing voltage, then, necessitates the use of a trolley wire overhead. Satisfactory trolley collecting devices have already been developed but much remains to be done in the way of making high trolley voltages safe. In D. C. use the trolley voltage is limited by the motors. Much higher voltages than 600 can not be successfully commutated on one commutator.

If two motors could be made to operate well in series and in that way double the trolley voltage, it would be possible to efficiently distribute the current to a distance of about 25 miles. In spite of the reasonableness of this scheme some engineers dismiss D. C. systems from serious consideration in connection with concentrated loading.

Several systems have been devised for using A. C. distribution at high trolley voltages. Some of these use D. C. and others A. C. motors. There is no voltage limitation in these systems, theoretically, which necessitates placing the power stations closer together than other conditions of economy require and the transforming equipment need be no greater than the motor capacity in use. All stations would be power houses and the great length of line fed from each station would make its load sufficiently constant for economical operation.

The most important of the proposed systems can be classified under three heads:

1st. Those using rotary apparatus on the locomotive for converting A. C. to direct, for the D. C. motors. The Ward-Leonard system is a notable example of this arrangement. It is particularly adapted for moving heavy trains.

2d. Those operating by means of induction motors requiring the polyphase distribution to the train. The tests at Zossen, Germany, were made with this system and although speeds up to 135 miles per hour were easily reached, this system has proven itself absolutely unsuited for general railway service.

3d. Those using a single-phase A. C. motor with the speed characteristics of a series D. C. motor.

The induction motor is inherently a constant-speed motor and is therefore not suited for traction. On the Continent there are several roads using polyphase induction motors, but the railway engineers of this country have been conservative and unwilling to introduce such a system which could not compete with standard D. C. systems. Their stand against the polyphase motor is justified by financial considerations and has not been due to any lack of progressiveness.

It is only within the last year that a successful single-phase A. C. motor has been developed and as yet it has not had a thorough test under the severe conditions of actual service. In order to have an efficiency and lightness at all comparable to the D. C. series motor its air gap must be made extremely small. Whether the air gap can be made small enough for the motor to have a good efficiency and at the same time stand up under usage, time alone can determine.

The fact that the motor can operate equally well on D. C. will doubtless hasten its development, and even though the motor does not succeed in solving the problem of concentrated service on heavy passenger and freight lines, it seems well suited to the lighter concentrated service of long interurban lines. Unfortunately the motor has a commutator which is, if anything, more troublesome than that of a D. C. motor. However, the voltage impressed on the motor need not depend on the trolley voltage, but can be transformed so as to give the best conditions for commutation.

A comparison of A. C. series with the D. C. series motor equipment does not show all the advantages to be in favor of the former. Nor is it probable that the A. C. system will ever displace the D. C. system in certain kinds of service. The car equipment for A. C. costs more than for D. C.; is heavier and of slightly lower efficiency except during acceleration. These disadvantages must be more than offset by the smaller amount of trolley copper and elimination of rotary sub-stations made possible by the A. C. motor in order for it to successfully replace its D. C. rival. It is likely that each system will have a place of its own.

The foremost engineers of the country are so contradictory in their opinions of the present status of the problem of A. C. versus D. C. and their predictions of the future development are likewise so diverse that there are evidently many points which cannot be definitely settled until further development takes place. The probability of the series A. C. motor revolutionizing electric traction is very remote.

On a system of very dense traffic heavy trains might not introduce a seriously great load on the station feeding even a comparatively short section, and it may be that some road like the New York Central will attempt the electrification of a considerable portion of their system along the same lines as their terminal plans now under way, i. e., using D. C. at standard voltage. If any line should make such a change it might be that competing lines would find their passenger traffic so reduced that in order to retain it they would be obliged to also electrify their passenger traffic. There is no doubt that the traveling public desires transportation by electric traction and that the change to electric by any steam road running fast long-distance passenger trains will bring about a great increase in the amount of business. Probably in no system will the outlay of capital for electric operation be as small as for steam operation, neither will the decrease of operating expenses under electric system pay for the interest on the larger invested capital, but the greater traffic and consequent greater earning capacity of the road *will* more than pay for the increase of outlay. Electrification means more than a mere change of equipment; it involves an improvement in traffic conditions which is bound to favor the electric system. The preference of the public for electric traction is shown in almost every case where an interurban line parallels a steam line. Practically all of the local traffic is taken from the steam line even though the schedule made by the interurban is slower. This competition has been felt so keenly by the managers of steam roads that they have attempted to prevent the building of electric roads paralleling their lines.

There have been a few cases where the steam railway has operated an electric road acquired because of competition as an auxiliary to their steam system. This is a legitimate undertaking and has the advantage of educating the steam railway managers to the advantages of electric traction. Some such educational process may be responsible for the change of attitude of steam railway engineers and managers which has occurred during the last year or two. In place of the hostility and skepticism of a couple of years ago regarding any encroachment of electric traction upon steam roads the present attitude is one of expectancy—of waiting for such developments as will permit of the use of electric locomotives in place of steam.

As the cost of fuel will necessarily increase with time, there will be an increasing necessity for changing from steam to electricity because of the better fuel economy of the stationary engine over the steam locomotive. The saving in cost is especially great when water power is available along the route.

In the rapid development of scattered interurban lines there has been little effort until recently to develop through traffic. In this respect the conditions are like the early days of steam railways when it was necessary to change cars fifty times between New York and Buffalo, when each individual road in trying to work out its own salvation lost sight of the necessity of working together for the common good of all. Fortunately for trolley lines the voltages used on D. C. systems are nearly all standard and there is no difficulty in consolidating systems and so developing long-distance service.

A general survey of the situation in this country indicates that the further developments in electric railways will occur as a gradual extension into the realm of steam railroads, rather than any sudden displacement of steam equipment. It is hardly possible

that in a period of six or eight years the electric locomotive will become a serious menace to the steam locomotive, although it is the firm belief of the writer that eventually all steam traction will be superseded by electric.

ELECTRICAL NOTES.

One of the curious possibilities of wireless telegraphy, and one also that shows how much remains to be accomplished in the way of perfecting detail before wireless telegraphy can command public confidence for public use, has recently been brought to light in Switzerland. There is at Fort Stoekli, on Mont St. Gothard, a wireless telegraphy station, which during the hot summer months has been subjected, especially during the hours immediately following midnight, to strange "influences" which for some time baffled the operators. These "influences" became stronger as the heat became more intense, and then the receiving apparatus solved the mystery by reproducing nightly, especially between midnight and 2 A. M., a series of messages—in English. The explanation was that owing to the marked presence of electricity in the atmosphere of the Alps during the high temperature, messages from Poldhu, in Cornwall, were reproducing themselves on Mont St. Gothard.

Wood poles for electric lines are treated by a new process in Switzerland which seems to have given good results. The process is applied to poles which are already in place in the ground. Around the base of the pole the ground is removed to two feet depth and the bared part is left to dry for two or three days. Then this part is given a layer of tar which is applied evenly up to a height of two feet or less above the surface of the ground. When this operation is finished, they place around the tarred wood an envelope of fibrine which is lightly fixed by means of large-head nails placed in the wood. A layer of tar is then placed upon this covering. Lastly, they apply around the pole and its covering a metallic cover, for instance of galvanized iron, which has been tarred on the inside surface so as to protect the fibrine against mechanical influences. When nailing the metal sheet around the pole, care is taken so as to make a tight application between the sheet, the fibrine covering and the pole. Sometimes the outer surface of the metal is also given a tar coating. These successive operations are easily carried out and at a low cost, especially where the poles can be treated before they are placed in the ground. The quantity of material which is needed for one pole is 0.25 to 0.30 square yard of ordinary or galvanized iron from 0.02 to 0.04; and some 0.5 to 0.7 square yard of fibrine and tar, making an outlay of $0.12 to $0.20. About an hour's work is needed for the operations.

The Financial Times, of London, asserts that views obtained from various experts on the Rand, in Africa, concerning the Victoria Falls power scheme, show that it will not be a financial success.

In the immediate vicinity of the Rand coal is both cheap and abundant, and water for condensing purposes can be obtained in practically unlimited quantities within forty miles of Johannesburg. Where coal is dear and water is scarce there is no question about the success of a cheap water-power installation, and this accounts for the success of such enormous undertakings as the Mexican Light and Power Corporation with an issued capital of $30,000,000, coal being unobtainable in Mexico city under about $7.50 per ton, and for the desire to operate by water power electric tramways and lighting plants in all the larger centers of South America where coal is equally dear. On the other hand, with unlimited coal at a low price and with modern electrical appliances, it is said to be very questionable whether the Victoria Falls can transmit power to the Rand in selling competition with that to be derived from such cheap coal. The longest transmission line at present working is said to be less than 200 miles, carrying an effective load of under 40,000 horse-power. The long distance from the falls to the Rand will interfere, the Times says, with the success of the movement.

Many factors enter into the problem of the economic generation of electric energy. Leaving aside the utilization of water power, wind power, and tidal power, the cost of fuel, and the economics of distant transmission, it remains to be true that the economic generation of electric energy is dependent on the cost of the prime power which serves as source, and this again depends on the type of prime mover adopted. If we assume steam as the medium by which the heat energy is to be translated into mechanical energy, and further, in any given case that steam at a given temperature and pressure is produced at a given cost per pound, then the chief economic questions which remain to be dealt with are the type of engine and the type of electric generator to be adopted, the size of unit of each, the nature of the electric supply as to whether alternating or continuous, and the appropriate voltage, together with the appropriate frequency and phasality if alternating. In many cases these latter electrical conditions are settled in advance, leaving as the main points to be decided the type of engine, the type of generator, and the size of units. Now, into any decision on these points there necessarily enters as a consideration of prime importance the question of speed; or rather perhaps one ought to say of speeds, for the speed of the generator is not necessarily the same as that of the engine which drives it. It is obvious that in the case where the prime mover is a gas engine, an oil engine, a water turbine, or a steam turbine, questions as to the most economic speed both of prime mover and of electric generator also arise.

ENGINEERING NOTES.

In some buildings, cold water *en route* to the feed-water heater is forced through coils placed in drip tanks and blow-off tanks for the purpose of utilizing some of the heat that would otherwise be wasted, and to provide for cooling the water that would cause injury to sewer connections if discharged at too high a temperature.

It is surprising with what swiftness the revolution has come that has made 500 to 600-foot vessels the commanding type on the Great Lakes. In the spring of 1904, when the "Augustus B. Wolvin," 560 feet over all, was launched, there was much headshaking, and predictions of financial failure were frequent. Owners of vessel property who were then discussing additions to their fleets were disposed to regard a conservative size as the final outcome of the timeworn discussion as to the most economical capacity for carriers of coarse freight. Where a merchant vessel interest ventured into the 450 to 475-foot class it was almost sure to hedge on the next boat placed by dropping down to 400 or 425 feet. It was said that the 10,000-ton boats could not be handled in some of the crowded harbors of lower lake ports, that tug expenses would be heavy, and that while large interests having docks of their own at the ports best prepared for quick dispatch of ore boats might find the big boats advantageous they were a type to be avoided by the independent vessel owner.—Iron Age.

In 1876 Canada did not possess a steel rail mill of any kind. To-day there are two situated some 1,500 miles apart; one practically on the shores of the Atlantic, and the other at the foot of Lake Superior. They naturally depend upon distinctly different sources for their supply of ore, fuel, etc. The eastern works are producing basic open-hearth rails from iron made in their own blast furnaces from near-by ores and fuel. The western one is so far depending upon the Bessemer process, but has one basic open-hearth furnace about completed. As yet the ores used by it are from Lake Superior deposits situated in the United States, and the coal and coke are brought from the States of Ohio, Pennsylvania, and Virginia. That this is at all possible well illustrates how low transportation charges have been brought. One of the two blast furnaces of this establishment is run on American ores and Canadian charcoal, and is making a record production. Both works are operating successfully, and enjoying bounties from the Canadian government, but as yet their production is not equal to the immediate demands of the Dominion.

It is generally conceded by the best of operating engineers, says the Electrical World, that in the majority of power stations there is a far better opportunity to make improvements in economy in the boiler room than in any other part of the plant. The reason for the indifference to boiler-room losses in the majority of plants otherwise well managed is probably that in the engine and generator part of the plant conditions are fixed to a much greater extent than in the boiler room. Once the valves of an engine are set correctly, an engine operates at best economy until some years of wear begin to tell upon it. The efficiency of the generator is practically fixed by the manufacturer. In the boiler room, on the other hand, the opportunities for variation of operating conditions are infinite. Almost everything depends on the skill and personal peculiarities of the men in charge. In the boiler room it is not a case of adjusting a piece of apparatus right and then simply operating it month in and month out. It is rather a case of eternal vigilance every minute of the day. No boiler plant can long be economical unless such vigilance is displayed.

In a paper recently read before the Société des Ingenieurs Civils de France, M. A. Mallet maintains that rack railways have sometimes been unnecessarily adopted in mountainous countries, and that better results would be obtained in many cases by dispensing with the rack entirely, and using simply adhesion locomotives. In support of his contention, he makes a detailed comparison of the Viege-Zermatt Railway and the Yverdon-Sainte-Croix line, which have very similar characteristics, with the exception that the latter is purely an adhesion line, while the former has long stretches of rack. Both lines are 1 meter gage, the Zermatt line being 21¾ miles long, and the other 15 miles. The difference in level between Viege and Zermatt is 3,150 feet, and between Yverdon and Ste. Croix 2,080 feet, so that the average gradient is 27.2 per 1,000 for the former, and 26.1 per 1,000 for the latter. The maximum gradient is, however, 1 in 8 for the Zermatt line, as against 1 in 21 for the other. Nevertheless, the rack railway has only 18 per cent of its length with gradients exceeding 1 in 33, while over 47 per cent of the total length of the other consists of such gradients. Each line is laid with rails weighing 49 pounds per yard, and each carries very nearly the same number of passengers per annum, though the Zermatt line is closed during eight months of the year. The cost of the Zermatt line averaged $41,250 per mile, as against $41,850 for the other. The trains taken are of very similar weight in both cases, being 58.7 tons on the Zermatt line and 64.8 on the Ste. Croix Railway; but the speed on the latter averages 14 miles per hour, as against 10 on its rival, and the running expenses are but 27 cents per train-mile, as against 54 cents on the other. Making all allowances for such differences as exist between the conditions of the two lines, M. Mallet concludes that an adhesion line between Viege and Zermatt would cost $100,000 more to construct than the existing railway, but that it would cost $5,000 per annum less in running charges and maintenance, and that the time taken between termini would be reduced by 34 per cent.

SCIENCE NOTES.

It is often claimed that there is no value in a sanitary analysis of a surface water, that an inspection of the watershed may give all, and often much more, information than can be obtained from the analysis of the water. If sewage is seen to be entering a pond, an analysis is unnecessary to show that it is polluted. If the watershed is uninhabited, the water cannot be polluted. There is no question about the value of a survey and that a survey not only aids in drawing the proper deductions from the data of an analysis, but that often it is necessary for a correct explanation of the data. Still, there are many cases where, unless large interests are involved, a careful and complete survey is practically impossible on account of the expense, and where the chief reliance must be placed on the sanitary analysis. Further, a survey alone, though it may show pollution, does not tell the amount of pollution, nor show the changes that have taken place in the polluting substances. A survey alone can never give all the desired information, and a sanitary analysis, even of a surface water, must always have a value.

Many of the results arrived at by the investigators into the phenomena of radio-activity can apparently only be verified by the lapse of considerable intervals of time. It is probable, for example, that we can estimate with some degree of accuracy the time required for the dissolution of half a given mass of uranium or radium, but the complete verification of our inferences must probably be left to a future generation. If we accept this view, it is our duty to provide our successors with data on which their conclusions may be based. If, for example, carefully determined masses of the more radio-active substances could be placed in such circumstances as to remain untouched for some hundred years, our successors, who would doubtless be equipped with apparatus of research more accurate and more sensitive than any in our possession, would at all events be placed in a position to establish by direct methods the accuracy of inferences based upon the experimental data now at our disposal.

In the early days of bacteriology it was claimed that the final criterion as to pollution of a water would be furnished by aid of that science, and though this hope has not been fulfilled, the information that can be gained by a bacterial analysis is often of the highest importance. It not only aids in the interpretation of the chemical data, but may of itself show, almost without question, that a given water is polluted, for though attempts to isolate special pathogenic germs have generally failed, even in waters known to contain these forms, characteristic sewage forms, like the colon bacillus, can be isolated if they occur in any number in a water. Occurrence of numerous characteristic sewage bacteria can point only to one thing, pollution, and if such forms are found there is no question that the water receives sewage drainage. Bacteriology, however, cannot determine, except very roughly, the amount of pollution, or the present condition of the polluting matter, nor does it give but very little, if any, information as to past pollution. If the pollution is recent and of any considerable amount, a careful bacterial examination will show the fact, and probably better and more convincingly than any chemical analysis. If the pollution is more remote, more information can, as a rule, be drawn from chemical than from bacterial data. If the polluting matter has filtered through the soil before entering the water, bacterial work will not indicate the fact.

The phenomena of ice formations at the bottom of lakes and rivers have been observed in Russia by J. de Schokalski. Such formation of ice is found in European Russia, Siberia, and Turkestan, in the rivers and in the lakes. The author had occasion to make careful observations as to the ice formation in Lake Ladoga, some 25 miles from St. Petersburg, and also took photographs of the phenomena. The first traces of ice formation were observed about the middle of November. He then made current researches until February, when the surface was covered with ice for thirty days. About the middle of March, after the ice broke, the same phenomena were reproduced. The nature of the bottom ice is quite different from that which lies at the surface. It is formed of a multitude of crystals having the form of flat plates, and these are connected together so as to form porous masses of ice which are sometimes three feet thick. When they are detached from the bottom and rise to the surface, these masses can break surface ice of half an inch thickness. The ice found in Lake Ladoga may be divided into different classes. When first forming at the bottom, the pieces have no well-defined structure, and are made up of small crystals mixed with mud and sand. Later on are seen other kinds, sometimes with fish-scale crystals which unite to form masses. Sometimes the floating pieces are like flat plates one-half inch thick and having one square yard surface and these are formed of flat ice scales reaching two inches width, loosely joined together at different angles. The base of the plate has an agglomerate of granular crystals upon which are deposited very small ice scales of varied forms. Sometimes the scales reach ten inches width and one-twenty-fifth inch thickness, and such scales are found at three feet depth on the lake bottom. They are also found floating separately under the surface ice. In an ice pile observed on the shore, the author found ice sheets over two feet long and one-eighth inch thick, which had come from the

bottom. Large ice plates are formed by the assemblage of such scales, and he noticed some plates measuring over five feet long, four feet wide, and fourteen inches thick. The cause of these phenomena is not yet made clear.

TRADE NOTES AND FORMULÆ.

Brown Varnish for Metals.—A varnish drying rapidly is made of 20 parts by weight of gum kino and 5 parts of gum benzoin in 60 parts of good alcohol. The preparation is made cold.

Gold Ink.—Commence by crushing gold leaf with honey. Remove the honey by washing with water, which leaves the gold finely pulverized. This powder will mingle with gum water of the desired consistency for an ink. It may be applied with a goose quill.

Putty for Parqueted Floors.—The following is recommended as an excellent putty for the joints of parqueted floors: Take lime, caseine, and umber with a little white and some black, so as to get the shade of the oak. Mix to a stiff paste and apply to the joints.

Open Water for Ducks in Winter.—Ducks will go into the water in winter even in the coldest weather. This is essential for their good condition. Care must therefore be taken that when the water freezes some portions are left free from ice. A good plan is to place fagots in the water near the edge. If these are withdrawn in the morning or during the day, a thin layer of ice will be removed at the same time.

Eau de Quinine Pinaud.—Tincture of cinchona 500 parts, spirits of wine 2,500 parts, eau de Cologne 250 parts, Jamaica rum 100 parts, pure alcohol 150 parts, spirits of soap 100 parts, quillaja bark 20 parts, balsam of Peru 10 parts, oil of bergamot 10 parts, oil of geranium 3 parts, oil of neroli 5 parts, tincture of cantharides 25 parts, castor oil 15 parts, anchusa 10 parts, turmeric 1 part. The whole should be digested for six days and then filtered.

To Keep Fir Branches Fresh.—The dark green color of fir trees is made use of in various ways for the decoration of rooms. The branches, together with the cones, give a very good effect when placed on the walls or in the corners or used as a background for flowers. To prevent the needles from falling off, the branches should be placed in a mixture of equal parts of glycerine and water. After the twigs have been steeped in this mixture, no fear need be entertained of the needles falling away. This process ought also to prove valuable for Christmas trees.

Preservation of Tanned Ox-Leather Belts.—These should be greased from time to time with a mixture of 1 part tallow, 4 parts train oil, 1 part colophony, and 1 part wood-tar, applied warm. The belts should never be placed on the pulley by hand, but with a special tool. Every new belt becomes stretched with use. It must then be unfastened and new holes bored in it to shorten it. In damp places or in the open air belts of gutta percha or of hemp or cotton covered with rubber are often substituted for those of leather.

To Clean Bronze Ornaments.—Boil the articles in ordinary soaper's lye; rinse out and roll in bran and sawdust. If the bronze is of the stamped variety, the lye must be mixed with salt. The ornaments should then be properly brushed, but no water must get to the back. A well-known method of cleaning gold-colored bronze articles consists in washing them in the above lye and brushing thoroughly with a brush, then passing them through a fluid made up of equal parts by weight of water, nitric acid, and alum, drying them with a rag and gently warming them.

A New Method of Utilizing Peat.—A new process for utilizing peat, by which solid substances, building materials, tubes, etc., are made from naturally moist peat with the addition of cement by applying pressure, has been recently patented. The cement is added without being moistened, and in such quantities that when the entire mass hardens, the moisture contained in the peat is absorbed by the cement. Moisture may also be withdrawn during the hardening process by heat. It has been noticed that the new mass is very durable; this can be explained by the fact that the cement draws the moisture necessary to its hardening from the peat, resulting in a close union and aggregation of the constituent parts. The substance prepared in this way is said to possess great strength and capacity for resisting the action of the atmosphere.

A Reliable Polishing Soap for Silver.—According to a communication in the Metallarbeiter (Vienna) a thoroughly reliable soap for polishing silver articles can be prepared as follows:

1. Take 80 parts of white or yellow soap cut in thin shavings, 18 parts of burnt magnesia, 2 parts of English red powdered fine, and a sufficient quantity of water. The soap should be dissolved in as small a quantity of water as possible, by heating, and the remaining ingredients then added.

2. For ordinary purposes the following can be recommended: 80 parts of good white or yellow soap cut in thin shavings, 4 parts of tripoli, 4 parts of ammonia alum, 4 parts of tartaric acid, 4 parts of lead carbonate, and a sufficient quantity of water. Mix as above.

3. The following is an excellent soap for cleaning silver, the only drawback being that the articles are liable to be scratched unless great care is taken in the preparation or selection of the powdered chalk: 100 parts of good white or yellow soap shaved thin, 4 parts of powdered tin-putty, 8 parts of sal-volatile, 16 parts of chalk powdered as fine as possible.

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